OPERATING AND INSTRUCTION MANUAL

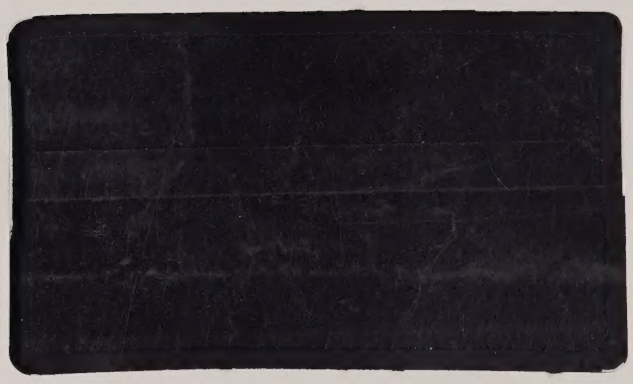
WITH PARTS LIST

DIGITAL PHASE ANGLE VOLTMETER
MODELS 220 and 225 -S-2878

FREQUENCIES: 400Hz 4.8KHz 29KHz

NORTH ATLANTIC

industries, inc.



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Circuits in this instrument are covered under
Patent No. 3,839,716

NORTH ATLANTIC INDUSTRIES, INC.
Hauppauge New York

Code Identification 07342

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BRUNING 40-135 32372

PHASE ANGLE VOLTMETER
+ 359.9
DEG
X 10⁻²
X 10⁻⁵
RATIO
MODEL 225 / RATIOMETER
NULL METER
NORTH ATLANTIC
REF
HI
LO
SIG
OFF LOCAL REM
SCALE ADJUST
IN OUT
REFERENCE OFFSET
±45°
RATIOMETER
RM
VM
TOTAL FUND IN PHASE QUAD PHASE ANGLE REF PHASE

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A D D E N D U M

DPAV 225

This addendum shows the corresponding frequency or ratio modes to the "F" numbers appearing on page 1.6 of the manual. The LOC column indicates the location of the frequency or ratio section in the DPAV. The FREQ column indicates the particular frequency or ratio frequency.

	LOC	FREQ
F1	_____	_____
F2	_____	_____
F3	_____	_____
F4	_____	_____

Nomenclature:

MB - Motherboard
C - Card
R - Ratio

S U P P L E M E N T

ALL 225 UNITS WITH OPTION 03

Remote Control/Digital Output Board DTL to TTL IC's

The following IC's have been changed from DTL logic to TTL on the Digital Output Board (see Schematic Figure 7.6 in the Manual for reference).

Z8, Z16, Z17, Z18 Z19, Z20, Z21	Were DTL Type 936 Now TTL Type SN7404N
Z11, Z12	Were DTL Type 946 Now TTL Type SN7400N

Parts List Change:		NAI P/N
Z8, Z16, Z17, Z18 Z19, Z20, Z21	IC Type SN7404N	806505
Z11, Z12	IC Type SN7400N	804883

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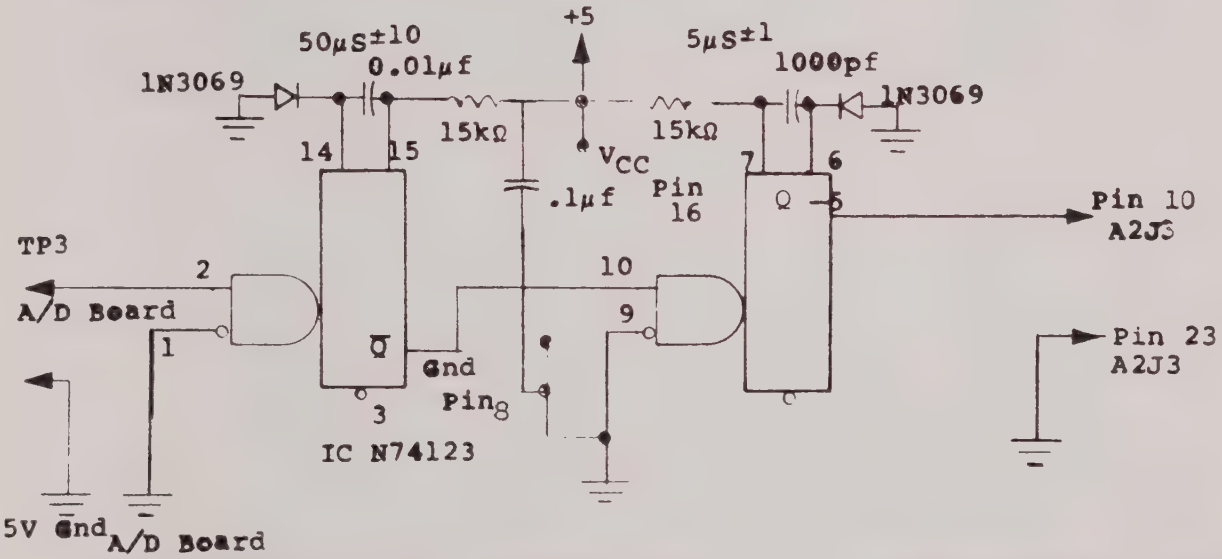
A D D E N D A

DELAYED STROBE

This addenda describes the delayed strobe added to this unit. It consists of a dual, single shot type N74123. The first section of the single shot produces a pulse of 50μS, the second, a pulse of 5μS, thus the delayed strobe of 50μS and the width of 5μS is obtained. The external connection point for this output source is located on the digital output connector J2. See schematic for details.



Board Input Connector (Ribbon Cable) — Digital Output Connector

J3-10 ⟩ Delayed Strobe ⟩ J2-31

J3-33 ⟩ GND ⟩ J2-32

Add to Parts List:

		NAI P/N
C1	Capacitor, Ceramic, .001μf, 600V, ±10%	800880
C2	Capacitor, Ceramic, .01μf, 25V	803406
C3	Capacitor, Ceramic, .1μf	806086
CR1, CR2	Diode, 1N914	806330
R1, R2	Resistor, Composition, 15kΩ, 1/4, ±5%	801988
Z1	I. C. Single Shot, SN74123	807722

CLAIMS FOR DAMAGE IN SHIPMENT

The purchaser should inspect and fuctionally test the Product(s) in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

SHIPPING

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

BRUNING 40-135 32372

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WARRANTY

A. The Seller warrants Products against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of Products which prove to be defective during the Warranty period. There is no charge under the Warranty except for transportation charges. The Purchaser shall be responsible for Products shipped until received by the Seller.

B. The Seller specifically excludes from the Warranty 1) calibration, 2) fuses, and 3) normal mechanical wear, eg, end-of-life on assemblies such as switches, relays, gear trains, etc. is dependent upon number of operations or hours of use, and end-of-life may occur within the Warranty period.

C. The Seller is not liable for consequential damages or for any injury or damage to persons or property resulting from the operation or application of Products.

D. The Warranty is voided if there is evidence that Products have been operated beyond their design range, improperly installed, improperly maintained or physically mistreated.

E. The Seller reserves the right to make changes and improvements to Products without any liability for incorporating such changes or improvements in any Products previously sold, or for any notification to the Purchaser prior to shipment. In the event the Purchaser should require subsequently manufactured lots to be identical to those covered by this Quotation, the Seller will, upon written request, provide a quotation upon a change control program.

F. No other Warranty expressed or implied is offered by the Seller other than the foregoing.

BRUNING 40-135 32372

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CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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SECTION I
GENERAL INFORMATION

1.1 INTRODUCTION AND DESCRIPTION

This manual describes the performance and operating features of Models 220 and 225 Digital Phase Angle Voltmeters (DPAV) together with information on calibration, maintenance, general troubleshooting and parts listing.

The primary function of the Phase Angle Voltmeter is to make the following measurements on an AC voltage:

1. TOTAL: Average of the rectified signal, including noise and harmonics (scaled in RMS).

2. FUNDamental: Fundamental voltage

3. IN-PHASE: Rectangular (vector) component of input voltage in phase with a reference input voltage of the same frequency. Polarity and magnitude of voltage is displayed.

4. QUADrature: Rectangular component of input voltage 90° out of phase with an input reference voltage. Polarity and magnitude of voltage is displayed.

5. PHASE ANGLE: The amount of phase shift in degrees by which the signal voltage leads the reference. The range is +0.0° to +359.9°.

In all measurement modes, except TOTAL, effects of noise and harmonics are rejected by an amount defined in the specifications.

A detailed breakdown of the features and options of Models 220 and 225 is provided in paragraph 1.3. The basic 220 is configured as a single frequency phase-sensitive voltmeter capable of measuring the FUNDamental, IN-PHASE and QUADrature voltages of the preselected frequency, plus broadband TOTAL mode measurements. The full complement of options can then be added as desired to satisfy individual requirements.

The Model 225 is a multi-frequency instrument with the PHASE ANGLE, REF PHASE and AUTORANGING options as standard, making it more suitable for broad general purpose applications.

In both models of the Digital Phase Angle Voltmeter, phase angle is measured by a unique (patent pending) type of signal processing designated the $TAN^{-1}GO^{TM}$ angle computation. Key features and options of the instruments are:

1. 10mV to 500V scaling (see specifications for maximum input)
2. Signal autoranging
3. 4-1/2 digit display
4. Reference Level automatic gain control
5. OVERLOAD and NO SYNC warning lights
6. 20% over-ranging
7. ±45° REFERENCE OFFSET adjustment
8. REMOTE CONTROL and DATA OUTPUT
9. REFerence and SIGnal isolation
10. 30Hz to 32kHz phase-sensitive frequency range
11. DC Recorder Output

The seven segment, 1/2" high, planar Beckman Display provides an easy to read, wide viewing angle readout. Range, function and warning lights are also displayed.

The general packaging approach is planar with most circuitry on large horizontal boards. This allows for ease of maintenance and troubleshooting.

1.2 SPECIFICATIONS

The following specifications apply to North Atlantic Industries' Models 220 and 225. Where a special modification or variation is involved, the governing specifications will be either a separate specification control document, the purchase order or a supplement contained in this manual. The options contained in an instrument are identified on the rear panel nameplate. The option numbers are in paragraph 1.3.

1.2.1 SIGNAL VOLTAGE RANGE: 10mV to 1000V rms in 6 ranges. 120% over-range.

1.2.2 MAXIMUM SIGNAL INPUT: 500V rms (±400VDC max.) for non-isolated, Broadband Isolation (Option 05) and DIRECT mode in Transformer Isolation (Option 04).

Determined by "F" rating in Transformer Isolation (Option 04). 0.75F at 400Hz where F = frequency in Hz. 0VDC without external coupling capacitor.

1.2.3 REFERENCE VOLTAGE RANGE: 0.2V to 200V rms, AGC (no adjust necessary) (±50VDC max.)

1.2.4 SIGNAL AUTORANGING: Up-ranges at 120% of range. Down-ranges at 10% of range. 330 milliseconds per range change.

1.2.5 DISPLAY: Beckman Information Display, 0.55" high indicates polarity and digital reading. Illuminated window indicates unit of measurement, mode overload and no sync condition.

Voltage: 4-1/2 digits, 0.01% full range resolution

Phase: +0.0° to +359.9° phase lead. 0.1° resolution.

1.2.6 FREQUENCY RANGE: TOTAL MODE: 30Hz to 100kHz

FUNDamental, IN PHASE, QUAD and ANGLE Modes: 1, 2, 3 or 4 frequencies from 30Hz to 32kHz, ±5% bandwidth.

1.2.7 WARM-UP TIME: **2 hours** for rated accuracy.

1.2.8 VOLTAGE ACCURACY:**

1.2.8.1 TOTAL Mode (Non-Isolated Mode)

	Accuracy(23°C±5°C)	Temp. Coef.(0-18°C,28-50°C)
60Hz to 30kHz	0.25% FS	0.01%/°C
30Hz to 100kHz	0.5% FS	0.02%/°C

TOTAL MODE Accuracy (Isolated Mode Only)

	Accuracy(23°C±5°C)	Temp. Coef.(0-18°C,28-50°C)
60Hz to 10kHz	±.25% FS	0.01%/°C
30Hz to 30kHz	±.5% FS	0.02%/°C
10kHz to 100kHz	±1% FS	0.04%/°C

1.2.8.2 FUND & PHASE SENSITIVE Modes

	Accuracy(23°C±5°C)	Temp. Coef.(0-18°C,28-50°C)
30Hz to 60Hz	0.05% FS +0.1% rdg.	(.003% FS +0.01% rdg)/°C
60Hz to 1.5KHz	0.05% FS +0.07% rdg.	(.003% FS +0.005% rdg)/°C
1.5kHz to 20kHz	0.1% FS +0.15% rdg.	(.004% FS +0.012% rdg)/°C
20kHz to 32kHz	0.15% FS +0.2% rdg.	(.005% FS +0.016% rdg)/°C

1.2.9 PHASE ACCURACY (PHASE ANGLE & REF PHASE MODES)

	(Accuracy-23°C±5°C) Display	Arc Tangent*	Temp. Coef. (0-18°C,28-50°C)
30Hz to 60Hz	0.25° ±1/2LSB	0.2°	.015°/°C
60Hz to 5kHz	0.2° ±1/2LSB	0.13°	.01°/°C
5kHz to 20kHz	0.25° ±1/2LSB	0.2°	.015°/°C
20kHz to 32kHz	0.35° ±1/2LSB	0.3°	.02°/°C

* For SIGnal level above 30% FS

NOTE: For an instrument with the Angle Mode Option (01), without the Autorange Option (02), the accuracy specification increases 50% when the SIGnal level is between 10% and 30% full scale.

1.2.10 ORTHOGONALITY

	(23°C ±5°C)	Temp. Coef. (0-18°C,28-50°C)
30Hz to 60Hz	0.15°	0.01°/°C
60Hz to 5kHz	0.09°	0.007°/°C
5kHz to 20kHz	0.15°	0.01°/°C
20kHz to 32kHz	0.2°	0.015°/°C

1.2.11 HARMONIC REJECTION

Fundamental & Phase-Sensitive Modes: 2nd and 3rd harmonic is 40db to 70db dependant on frequency. All other harmonics will vary with frequency and harmonic order.

**Noise & Offset

Accuracy at zero input, in the voltage measuremnet modes, is defined as the ___% FS statement in the various specifications. Total Mode, 10mV range, noise specification is 35uV.

1.2.12 **COMMON MODE REJECTION - Broadband Isolation (10mV Range)

Source Impedance	In-Phase 0Ω	In-Phase 100Ω	Quad 0Ω	Quad 100Ω
30Hz to 5KHz (min.)	126db	110db	126db	87db
5KHz to 32KHz(min.)	100db	92db	106db	71db
400Hz (typ.)	132db	126db	132db	114db

300V rms maximum common-mode voltage. Source impedance in signal high lead.

1.2.13 COMMON MODE REJECTION - Transformer Isolation

400Hz 97db min. (zero source impedance)
88db min. (1KΩ source impedance)

1.2.14 SIGNAL INPUT IMPEDANCE:

Transformer Isolation: 400KΩ at 400Hz (0.75F max. input volt.)

Broadband Isolation: 10MΩ shunted typically by 75pf (140pf with Option 07 or 08)

Non Isolated Input: 10MΩ shunted by typically 60pf (125pf with Option 07 or 08)

1.2.15 REFERENCE INPUT IMPEDANCE:

500KΩ shunted by typically 25pf (71pf with Option 07 or 08)

1.2.16 RESPONSE TIME TO RATED ACCURACY:

Phase-Sensitive and Angle Modes: Typical, 1.5 seconds
Maximum, 6 seconds

TOTAL Mode: Typical, 1.5 seconds
Maximum, 10 seconds

The maximum response time occurs under worst case conditions of mode selection, input overload and autoranging.

1.2.17 REMOTE CONTROL/DIGITAL OUTPUT (Option 03)

Remote control input and digital outputs are interfaced at rear panel connectors J1 and J2 respectively.

Positive logic is DTL, TTL compatible and in static parallel form.

1.2.17.1 Signal Description

Remote Control Inputs: Low ("0") = 0V to +0.4V (-1.5mA maximum)
High ("1") = +2.4V to +5.5V

**Rejection is minimal at upper end of frequency band and is generally higher at lower frequencies.

1.2.16.2 Digital Outputs

Low ("0") = 0V to 0.5V, 12mA maximum sink current
High ("1") = +2.4V to +5V, 6kΩ source resistance

1.2.16.3 MODE TRUTH TABLE

	Remote Control (J1) Pin 5	6	7	Digital Output (J2) Pin 37	36	25
TOTAL	0	0	1	0	0	1
FUND	0	1	0	0	1	0
IN-PHASE	0	1	1	0	1	1
QUAD	1	0	0	1	0	0
PHASE ANGLE	1	0	1	1	0	1
	J1 Pin 1			J2 Pin 17		
REF OFFSET	1			1		

1.2.16.4 RANGE TRUTH TABLE

	Remote Control (J1) Pin 2	3	4	Digital Output (J2) Pin 19	18	16
10mV	0	0	0	0	0	0
100mV	0	0	1	0	0	1
1000mV	0	1	1	0	1	1
10V	1	0	0	1	0	0
100V	1	0	1	1	0	1
1000V	1	1	1	1	1	1
Auto	1	1	0			

1.2.16.5 FREQUENCY TRUTH TABLE

	Remote Control (J1) Pin 8	15	Digital Output (J2) Pin 35	34
F1	0	0	0	0
F2	0	1	0	1
F3	1	0	1	0
F4	1	1	1	1

1.2.16.6 DATA OUTPUT (BCD) J2

	Pin 33		Pin 13
Polarity +:	1	Over-range 1:	1
-:	0		

	Most Sig. Digit				Next M.S.D.				Next L.S.D.				Least S.D.			
	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1
J2 Pin:	12	10	9	8	7	6	5	4	1	2	3	24	23	22	21	20

1.2.14.7 OVERLOAD FLAG — J2-15

Signal Overloaded: 1 (pulsing)

NO SYNC FLAG — J2-14

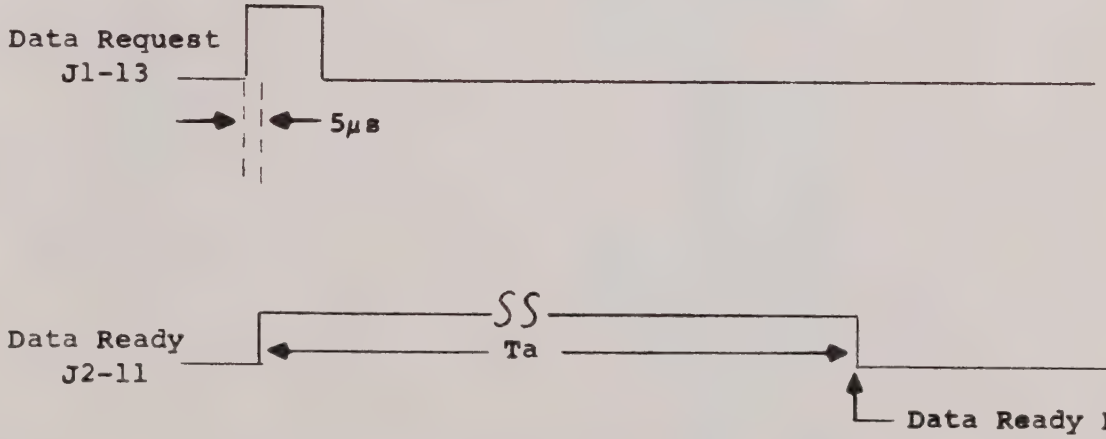
Out of Sync: 1

1.2.14.8 DATA REQUEST/READY

Data Request Pulse: Logic "1" for from 25μs to 1 sec. duration.

Data Ready: Logic "1" pulse whose leading edge trails Data Request leading edge by approximately 5μs; trailing edge to logic "0" is the Data Ready flag. The duration is a function of state of system, i.e., whether it is ranging, overloaded, out of sync.

TIMING DIAGRAM



Where the unit is not ranging, or overloaded or out of sync, Ta is approximately 2.5 seconds.

If, after a Data Request pulse, the unit is ranging, out of sync or overloaded, the Data Ready flag will occur 2.5 seconds after the unit reaches a stable operating condition.

Where the unit is in TOTAL mode and is overloaded after Data Request, the Data Ready flag will occur approximately 6 seconds after unit comes out of overload.

1.2.17.9 CONNECTOR WIRING

Remote Control (J1)

Pin 1	REF OFFSET	Pin 9	Ground
2	Range Remote Control	10	Spares
3		11	
4		12	
5	Mode Remote Control	13	Data Request
6		14	+5V
7		15	FREQ SELECT
8	FREQ SELECT		

Digital Outputs (J2)

Pin 1	"8" of next LSD	Pin 20	"1" of LSD
2	"4" of next LSD	21	"2" of LSD
3	"2" of next LSD	22	"4" of LSD
4	"1" of next MSD	23	"8" of LSD
5	"2" of next MSD	24	"1" of next LSD
6	"4" of next MSD	25	Mode Output
7	"8" of next MSD	26-32	Spares
8	"1" of MSD	33	Polarity
9	"2" of MSD	34	FREQ SELECT Output
10	"4" of MSD	35	FREQ SELECT Output
11	DATA READY	36	Mode Output
12	"8" of MSD	37	Mode Output
13	Over-range Digit		
14	OUT OF SYNC Flag		
15	Overload Flag		
16	Range Output		
17	REF OFFSET		
18	Range Output		
19	Range Output		

1.2.18 DC RECORDER OUTPUTS (OPTION 06)

IN-PHASE and QUADrature DC outputs are available at rear panel. TOTAL and FUNDamental DC voltages appear at IN-PHASE terminals when unit is in appropriate mode. Low terminal is instrument circuit ground.

Full Scale Output: ±8.75V ±5%
Output Impedance: 2kΩ
Linearity and Stability: Same as specification for TOTAL, FUND, IN-PHASE and QUAD modes.

1.2.19 MECHANICAL SPECIFICATIONS

Size:	Panel is 5-7/32" x 19"
	Depth behind panel: 15"
	Width behind panel: 16-3/4"
Weight:	30 lbs. net, 35 lbs. shipping
Mounting:	Rack or bench mounted
Front Panel Paint:	Semi-Gloss Gray #26280 (Dress Panel) #26132 (Sub-Panel)
Line Cord:	6' long with ground pin
Front Panel Input:	Inputs are standard, 5-way binding posts, spaced on 3/4" centers

Specifications subject to change without notice

1.3 OPTIONS AND FEATURES

1.3.1 Tabulation

STANDARD & OPTIONAL FEATURES	MODEL 220	MODEL 225
TOTAL, FUNDamental, IN-PHASE & QUADRATURE Voltage Modes and Reference Isolation	Included	Included
Phase-Sensitive Frequencies Included	1	2
Optional Frequencies	N/A	3rd or 4th
ANGLE MODE & ±45° PHASE OFFSET	Option 01	Included
Auto Ranging	Option 02	Included
Remote Control & Digital Output	Option 03	Option 03
Transformer Isolation (Signal)	Option 04	N/A
Broadband Isolation (Signal)	Option 05	Option 05
DC Recorder Output (VOLTAGE Modes Only)	Option 06	Option 06
Rear Input Connectors (Signal & Reference) MS Type: / Terminal Strips:	Option 07 / Option 08	Option 07 / Option 08
Special Custom Variation (Contact Factory)	Option 09	Option 09
Rack Mount Adapter & Ribbon Cable Removal Tool	Included	Included
Ratio Option	See Section IX	
Null Meter	Option 10	Option 10

1.3.2 TRANSFORMER ISOLATION (OPTION 04), Schematics Figures 7.2b, 7.2e

This option consists of double shielded isolation transformers connected directly to the SIGnal and REFerence input terminals to allow for common mode differential measurements and also elimination of ground loops.

On the SIGnal side, a DIRECT-TRANSFORMER switch permits selection of unisolated 10MΩ direct input or transformer isolation at the instrument's phase-sensitive frequency. The switch connections are shown in Figure 7.2b.

1.3.3 BROADBAND ISOLATION (OPTION 05), Schematics Figures 7.2b, 7.2e

This option consists of isolated modules and shielded transformers at the SIGnal and REFerence inputs. The ±15V power supply for the modules is provided by isolated windings on the Power Transformer.

The input divider relays are operated by a light bulb and phototransistor combination to minimize coupling between the isolated circuitry and the circuit ground of the instrument.

When this option is present, some of the front end circuitry on both the SIGnal and REFerence side is removed from the Main Board since the equivalent circuitry is in the modules.

1.3.4 DC RECORDER OUTPUTS (OPTION 06)

IN-PHASE and QUADrature DC outputs are available at rear of panel. TOTAL and FUNDamental DC voltages appear at the IN-PHASE terminals when the unit is in the appropriate mode. The LOW terminal is the circuit ground.

Full Scale Output: ±8.75V ±5%
Output Impedance: 2kΩ

1.3.5 REAR INPUT CONNECTORS (SIGNAL & REFERENCE) (OPTION 07, 08)

a) OPTION 07 - MS Type Connectors
SIGnal and REFerence wired to front panel terminals
Hi Terminal: Pin A
Lo Terminal: Pin C

b) OPTION 08 - Terminal Strips
SIGnal and REFerence rear panel inputs wired to front panel

terminals. Hi and Lo designations are screened on rear panel.

1.3.6 NULL METER (OPTION 10)

This option consists of a center null analog meter mounted on the front panel. It gives the operator the advantage of the relative magnitude and direction of the voltage the DPAV is measuring. It is especially useful in the ratiometric mode.

1.3.7 GROUNDING LINKS

The DPAV signal input is provided with one of the following:

1) Direct Mode Input
2) Transformer Isolation Input
3) Broadband Isolation Input

The grounding links for each are:

1) Direct Mode Input - Refer to schematic figure 7.2b.
   The front panel signal input posts consist of:
   a) Red = Hi Line Input
   b) Black = Lo Line Input, Signal Ground
   c) Ground post = chassis ground (ground post has link to connect to Lo Line, if desired)

2) Transformer Isolation Input - Refer to schematic Fig. 7.2b
   The front panel signal input posts consist of:
   a) Red (upper) = Switchable for Transformer Hi or Direct Hi
   b) Red (lower) = Switchable for Transformer Lo or Signal Gnd
   c) Black = Signal Ground (a rear panel link connects chassis ground to signal ground, if desired)

3) Broadband Isolation - Refer to schematic 7.2b.
   The front panel input signal posts consist of:
   a) Red (upper) = Hi Signal Input
   b) Red (lower) = Lo Signal Input and Isolation Ground
   c) Black = Signal Ground (A rear panel link connects chassis ground to signal ground, if desired.)

1.4 APPLICATIONS

A. Phase-Sensitive Null Indicator

B. Measures separately the IN-PHASE and QUADrature components of an AC signal.

C. Measures phase shift in any AC system.

D. Sensitive AC electronic voltmeter

E. Testing of servos, computers, synchros, resolvers, inductosyn.

F. Precise AC ratiometry.

G. Phasing of servo motors, chopper amplifiers, magnetic amplifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks.

J. Impedance meter

K. Power factor meter

L. Measuring response of vibrational system.

M. ATE applications

SECTION II
PREPARATION FOR USE

2.1 INITIAL INSPECTION

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage results from the typical handling encountered during shipment. However, upon removal from the package, the instrument should be externally inspected for any obvious damage. Should such damage be observed, refer to the Warranty in Section VIII. The instrument may now be mounted (either rack or bench) and checked per Performance Evaluation Procedure (paragraph 5.5).

2.2 INSTALLATION

Models 220 and 225 require no special cooling equipment, but it is recommended that the unit be mounted in such a manner as to allow the free flow of air around the unit, especially the rear panel which is used to transmit the power supply heat to the ambient.

Operation is limited to a maximum ambient temperature of 50°C (122°F) and a minimum of 0°C (32°F).

2.3 BENCH MOUNTING

Plastic feet are mounted on the bottom of the unit making it ready for use as a bench instrument.

2.4 RACK MOUNTING

For mounting in a standard 19" rack remove plastic feet (replacing screws) and install the rack mounting brackets (NAI P/N 205361) on the side panels in the front of the unit. The existing four screws are removed and the bracket installed using screws supplied with the bracket.

SECTION III
OPERATING INSTRUCTIONS

3.1 INTRODUCTION

This section describes the operating modes and required inputs of the instrument. The SIGnal and REFerence inputs are applied to the front panel Grayhill terminals (rear panel option available) and the operating controls are front panel push buttons (Remote Control and Digital Output Option available).

The unit is fully automatic and the only manual adjustment required is setting of the REFerence PHASE front panel pot when required.

Measurements can be made approximately 45 seconds after turn-on, but for rated accuracy, there is a one-half hour warm-up time.

It is recommended that the unit not be left in an overload condition since there are reed relays cycling in the unit when an overload condition exists.

3.2 POWER REQUIREMENTS

Models 220 and 225 are designed for either 115V or 230V nominal line voltage, 45-440Hz. Power dissipation is 30VA maximum with all options.

The operating line voltage is selected by an internal slide switch (S4) mounted on the Main PC Board near the power transformer. The line voltage for a particular instrument is factory set and is designated on the rear panel.

For 115V operation the rear panel fuse is 0.5 ampere Slo-Blo. For 230V operation the fuse is 0.25 ampere, Slo-Blo.

To convert from one voltage to another, select appropriate switch position and fuse.

3.3 GROUNDING

The instrument chassis is connected to the round ground pin of the three prong power plug. Normal operation of the instrument is with the internal circuit ground connected to chassis ground. Depending on the application, this can be done by a rear panel link or externally in the measurement set-up.

Extreme caution should be taken in any special application where the instrument chassis is not connected to house ground.

3.4 REFERENCE INPUT

The fundamental component of the AC signal applied to the REFerence input is the 0° phase reference for the instrument.

The REFerence level must be in the range from 0.2V to 200V rms. The frequency range is ±5% around the specified instrument phase-sensitive frequency (or frequencies in the case of Model 225).

The REFerence input is applied to AGC circuitry, eliminating the need for manual level adjustments. Since the REFerence level is normally constant, the AGC loop is not particularly fast and may take a few seconds to stabilize at turn-on or after a level shift.

The NO SYNC warning light will go on if there is no REFerence signal when the instrument is in the phase-sensitive modes (IN-PHASE, QUAD or ANGLE modes). It will also go on if the frequency differs from the center frequency by more than about 8%.

As mentioned in Section I, there are REFerence and SIGnal isolation options available. Isolation is used in applications where common mode voltages are present or where ground loops can cause significant measurement errors.

For instruments whose REFerence input is not isolated or for those with Broadband Isolation (Option 05), 200V rms is the maximum input. For instruments with Transformer Isolation (Option 04), the maximum input at any frequency is determined by the F rating of the transformer with 200V as a maximum. For example, at 400Hz the Isolation Transformer has an F rating of 0.75F, where F is the frequency in Hz. Thus the transformer rating limits the input voltage to 0.75 x 400 = 300V, which, in this case, is not the limiting factor since it exceeds the 200V limit.

A rear panel REFerence and SIGnal input option is available. See specifications for increase in input shunt capacity.

3.5 SIGNAL INPUT AND RANGE

As with the REFerence input, isolation options are available where ground loops or common mode voltages are present.

For non-isolated or Broadband Isolated (Option 05) SIGnal input, the maximum input level is 500V rms over the specified frequency range. For Transformer Isolation (Option 04), the maximum input level at any frequency is determined by the F rating of the transformer with 300V rms as a maximum. In the DIRECT mode of Option 04, the maximum voltage is 500V rms.

There are six full scale ranges from 10mV to 1000V (500V maximum) and autoranging.

A 20% over-range (except in 500V scale) allows for more accurate readings at input levels higher than full scale, instead of ranging to a less sensitive scale. At input levels exceeding 1.2 times full scale, the OVERLOAD light will flash as a warning. If unit is in AUTORANGE, a range change will occur automatically. The AUTORANGE down-ranges at the 10% full scale level. The 10% and 120% full scale threshold levels are not exact and may differ from nominal levels. Autoranging operates at approximately 330 milliseconds per range. A rear panel REFerence and SIGnal input option is available. See specifications for increase in input capacity.

3.6 FUNCTION SELECT

A front panel push-button assembly, consisting of six switches, allows for the selection of the desired measurement. Reference Offset is controlled by an ON-OFF push-button switch and pot.

3.6.1 TOTAL: In this mode, the instrument acts as a conventional AC voltmeter, measuring the average rectified signal input with all harmonics and noise over a frequency range of 30Hz to 100kHz.

3.6.2 FUNDamental: Measures the fundamental vector component of the input signal. No REFerence input is required for this measurement, but a signal level must be greater than 1% of full scale. This is 100μV on the 10mV scale. Measurements below this level are possible, but the phase lock loop may be unable to "capture" the low voltage if it goes out of lock.

Another way to measure FUNDamental is to null either the IN-PHASE or QUAD voltage with the REFerence OFFSET knob and read the other phase sensitive component. Thus, if the input signal has a phase lead of, say, +80°, one could null the IN-PHASE by off-

setting the REFerence PHASE by -10° and read the QUAD which will equal the fundamental component of the signal.

3.6.3 IN-PHASE: Measures the in-phase vector component of the input signal, displaying amplitude and polarity. This reading will be affected by the status of the REFerence OFFSET control.

3.6.4 QUADrature: Measures the quadrature vector component of the input signal, displaying amplitude and polarity. This reading will be affected by the status of the REFerence OFFSET control.

3.6.5 PHASE ANGLE: Measures and displays the phase angle in degrees between the SIGnal and REFerence inputs.

In this mode the unit is automatically placed into an autorange mode. In order to keep the AC levels in the instrument as high as possible (to minimize errors at low input levels) ranging occurs between 0.3 and 1.2 times full scale, resulting in an equivalent of 12 scales. Thus, depending on the number of ranges the unit must go through when put into PHASE ANGLE mode, the ranging could take as long as four seconds, worst case.

This reading will be affected by the status of the REFerence OFFSET control.

3.6.6 REFERENCE PHASE: The equivalent reference phase may be changed by means of the front panel REFerence OFFSET pot. The REFerence PHASE mode measures and displays in degrees the amount the reference is phase shifted. With the REFerence OFFSET button off, the reading should be 0.0° to within specified tolerance.

3.6.7 REFERENCE OFFSET: With the IN button depressed, a reference phase offset is produced, the magnitude of which is controlled by the knob setting. The range is ±45°. The amount of offset can be read by putting unit in REFerence PHASE mode.

The IN-PHASE, QUADrature and PHASE ANGLE modes will be affected by this setting, since the 0° reference

input vector is being rotated by the offset.

In applications where the reference phase is being offset in order to null a quadrature voltage, it is best to monitor the QUAD voltage for a more sensitive null.

3.7 NO SYNC and OVERLOAD Warning Lights

The NO SYNC light will go on if there is no REFerence signal or if the reference frequency is different from the selected phase sensitive frequency by more than approximately 8%. The NO SYNC light is disabled in the TOTAL mode.

The NO SYNC light may go on for a couple of seconds when switching into or out of the FUNDamental mode. This can be caused by a step change in the phase of the signal going into the phase lock loop, resulting in a transient"out-of-lock" condition. It can also be caused by a transient response of the AGC loop responding to the different REFerence and FUNDamental voltage levels.

Any readings taken while the NO SYNC light is on are not valid.

3.8 Remote Control/Digital Output Option

This option provides for computer interfacing and control of the DPAV. With the REMOTE push button depressed, all functions (except REFerence OFFSET knob position) are programmable through the option card mounted on the rear panel. The 16 wire ribbon cable and the single jumper wire carry the control signals from the option card to the front control section of the DPAV. J1 connector on the rear panel is for the programming inputs.

The digital output signals are fed to J2 on the rear panel. They are derived from signals coming from the A/D Board via two 26 wire ribbon cables to the option card.

The DPAV will issue a Print Command on J2 pin 11 in response to a Data Request input on J1 pin 13 after a delay dependent on the state of the instrument. That is, consideration is taken as to conditions of NO SYNC, OVERLOAD, Ranging and Mode to determine appropriate delay.

Details on this option are given in the Specification Section. and in paragraph 4.5.

3.9 Differential Measurements and Common Mode Rejection

The following describes the general sources of error when making a differential measurement in the presence of a common mode voltage. The examples describe simple transformer isolation, but the principles are the same with the Broadband Isolation Option. The only difference is an isolated amplifier in series with the high side of the transformer primary.

In making differential measurements using a transformer, there are two sources of error. One is due to capacity from either side of the primary to the high side of the secondary as shown in Figure 3.1. This can result in an output even if E1 = E2, due to coupling into the output impedance of the secondary. This effect is minimized if a secondary shield is used, connected as shown in Figure 3.2. Note that these capacitors are now capacitors to ground and will cause no coupling to the secondary.

The other source of error is capacity to ground, phase shifting the signal from a source with a finite source impedance as shown in Figure 3.3. This can also cause an output even if E1 = E2.

This effect is minimized if a double shielded wire and a primary shield are used as shown in Figure 3.4. This will connect the capacity from the inner conductor to the inner shield (C1) across the transformer which, when nulled, introduces no error. Capacity from the inner to outer shield (C2), and capacity from the primary shield to secondary shield (C3) is across E2. If E2 has a low source impedance, this will introduce no error.

Therefore, the lowest impedance source should be connected to the low input terminal for maximum accuracy in making differential measurements.

Where making differential measurements when high source impedances are present in both input leads is desired, it is sometimes possible to "drive" the primary shield at a voltage equal to E1 and E2. This, in effect, places C3 and C2 across a third source independent of the voltages being measured. This is shown in Figure 3.5.

3.9.1 Common Mode Rejection (CMR) - Defines the ability of an instrument to measure a voltage existing between its two input leads (Differential Mode Voltage) in the presence of a voltage to ground common to both input leads (Common Mode Voltage). This type of measurement is frequently encountered when making ungrounded or differential measurements such as the output of AC Bridges.

Common Mode Rejection, expressed in per cent, is defined as:

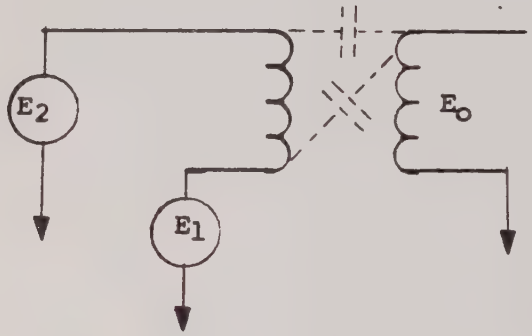
$$\frac{\text{Differential Output}}{\text{Common Mode Voltage}} \times 100\%$$

It can be measured by shorting the input leads together and applying a Common Mode Voltage to both input terminals (Figure 3.6) and reading the output of the meter. To measure CMR with a source resistance, use the circuit of Figure 3.7.

An example of this calculation would be the meter reading 10mV with a CMV of 100V. The CMR would then be

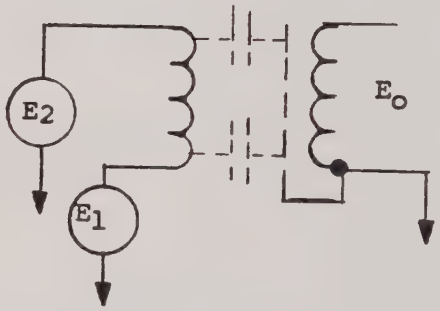
$$\frac{10 \times 10^{-3}}{100} \times 100 = 0.01\%$$

DIFFERENTIAL MEASUREMENTS, SHIELDED TRANSFORMER



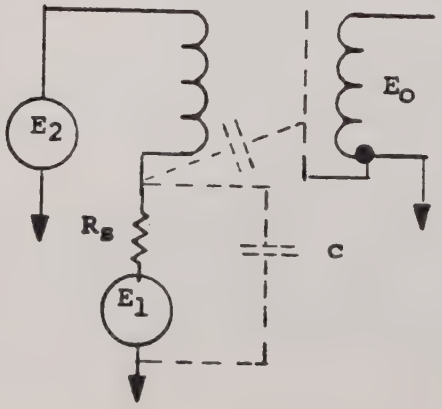
← FIGURE 3.1

DIFFERENTIAL MEASUREMENTS, SECONDARY SHIELD



← FIGURE 3.2

DIFFERENTIAL MEASUREMENTS WITH SOURCE IMPEDANCE



← FIGURE 3.3

DIFFERENTIAL MEASUREMENTS, DOUBLE SHIELDED

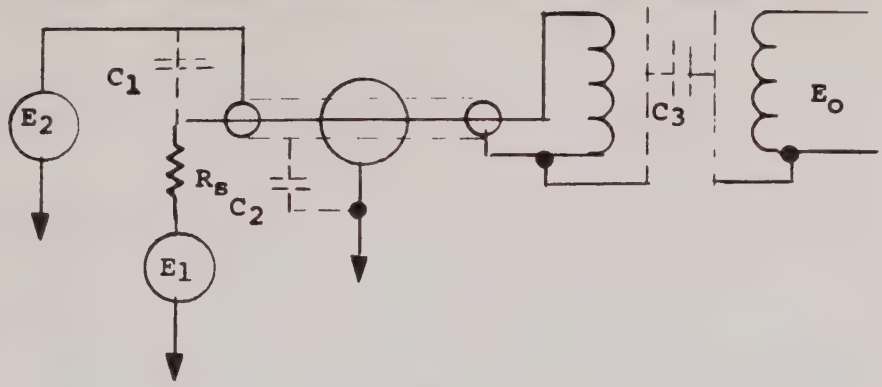


FIGURE 3.4

DIFFERENTIAL MEASUREMENTS, DRIVEN SHIELD

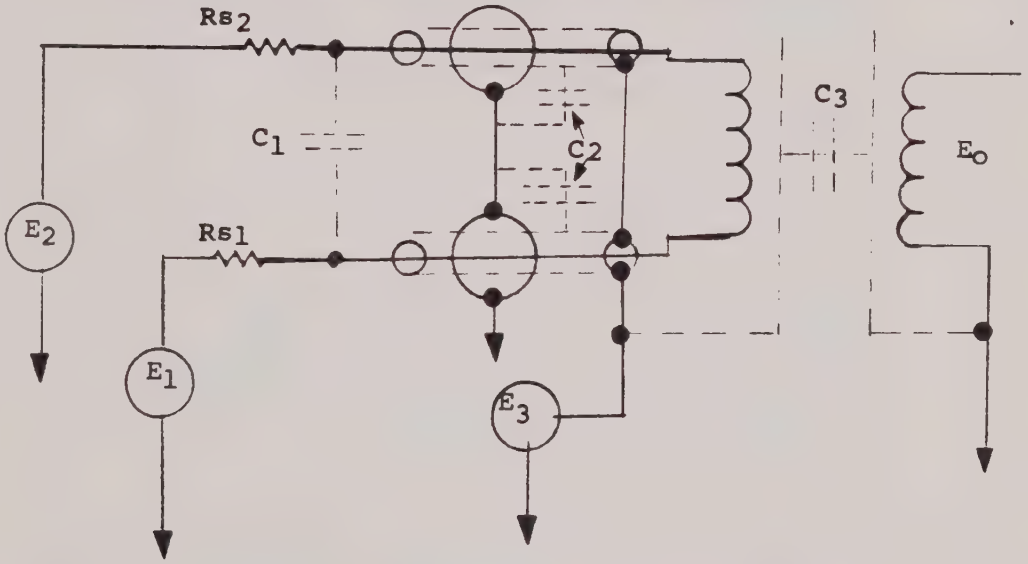


FIGURE 3.5

DIFFERENTIAL MEAS. COMMON MODE INPUT

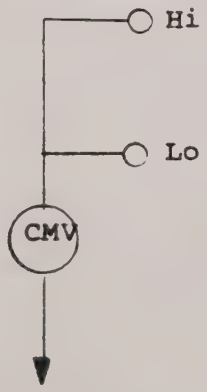


FIGURE 3.6

DIFFERENTIAL MEAS., COMMON MODE INPUT WITH SOURCE IMPEDANCE

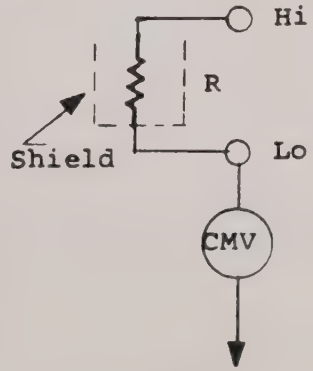


FIGURE 3.7

3.10 REAR SIGNAL AND REFERENCE CONNECTORS (MS)

Signal and reference input terminals are connected in parallel to Pins A and C of connectors on rear panel. Use of the jumper on front terminals will duplicate connections of rear connector. The rear connector is MS3102A-10SL-3P. (Its' mating connector is MS3106A-10SL-3S.) Connections are as follows:

Signal Front Terminal	Rear Connector
Hi	A
Lo	C

Reference Front Terminal	Rear Connector
Hi	A
Lo	C

SECTION IV
THEORY OF OPERATION AND BLOCK DIAGRAM DESCRIPTION

4.1 INTRODUCTION

The basic measurement task of the phase-sensitive voltmeter can be described in terms of the time domain equation of a sinusoidal voltage containing harmonics and noise, and phase shifted from a reference sinusoid by θ degrees:

$$E_s = E_1 \sin(\omega t + \theta) + E_2 \sin 2\omega t + E_3 \sin 3\omega t \ldots E_n \sin n\omega t + N(t)$$

A vector diagram of the fundamental voltage is shown in Figure 4.1

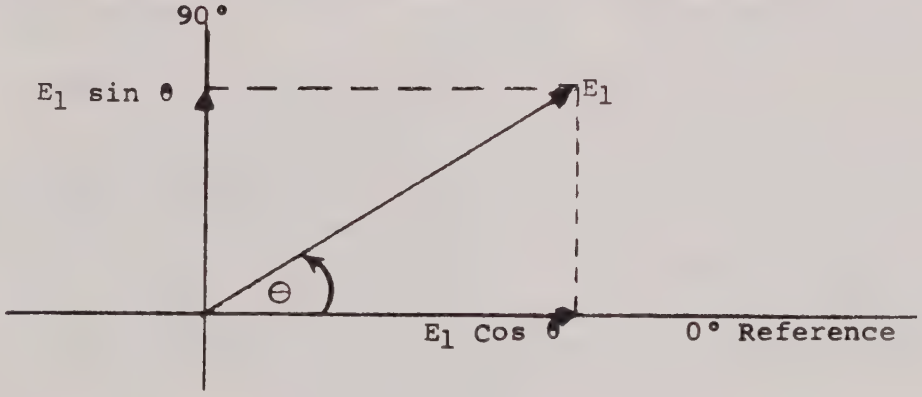


FIGURE 4.1

The digital phase angle voltmeter measures the polar coordinates (E_1 and θ) and the cartesian coordinates ($E_1 \cos \theta$ and $E_1 \sin \theta$) of the input voltage represented as a vector. Effects of harmonics and noise are rejected. The basic phase-sensitive vector voltages are extracted by a process of demodulation or multiplication and are in the form of DC voltages.

Consider the familiar trigonometric identity

(1) $\sin(x + y) = \sin x \cos y + \cos x \sin y$

this leads to: $\sin x \cos y = 1/2 \sin(x + y) + 1/2 \sin(x-y)$; i.e. multiplication of 2 sinusoids leads to sum and difference terms and if $x = \omega t + \theta$, and $y = \omega t$ (corresponding to REFerence input)

Thus, (2) $E1 \sin(\omega t + \theta) \cos \omega t = \frac{E1}{2} \sin \theta + \frac{E1}{2} \sin(2\omega t + \theta)$

and if the input signal is multiplied by sin ωt

(3) $E1 \sin(\omega t + \theta) \sin \omega t = \frac{E1}{2} \cos \theta - \frac{E1}{2} \cos(2\omega t + \theta)$

The DC terms on the right side of equations 2 and 3 are the desired signals. $\frac{Es}{2} \sin \theta$ is proportional to the QUAD component and $\frac{Es}{2} \cos \theta$ is proportional to the IN-PHASE component.

The cartesian coordinates are referred to as "In-Phase" and "Quadrature" vector components of the input.

In the TOTAL mode, a measurement of the average of the rectified input is made.

All voltage measurements are calibrated in rms.

The basic instrument is divided into two functional sections. The circuitry on the large main board performs signal processing which converts the pertinent characteristics of the AC signal input into DC voltages.

The two upper boards (Read-Out and A/D Boards) comprise the analog-to-digital converter and display.

4.2 MAIN BOARD BLOCK DIAGRAM DESCRIPTION

A simplified block diagram of the Main Board is shown in Figure 4.2. The following is a cursory description of the function of each major circuit block and its inter-relation with the other blocks. Refer to the schematics of Figure 7.2 and block diagram of Figure 4.2 (Schematic - Figure 7.2.b).

4.2.1 Signal Channel Front End

The input signal is fed to a 1000:1, 10MΩ broadband divider and then to a high impedance FET amplifier (Q8) which provides impedance transformation and amplification.

The output of this FET Amplifier is fed to a 3 resistor decade divider and a high input impedance buffer amplifier Z9.

The output of Z9 is fed to the input of the Autoranging Block, TOTAL rectifier and signal AC filter.

The 1000:1 divider and the three decade divider provide the six range changes from 10mV full scale to 500V full scale (see maximum voltage limitations).

The range changing is controlled by either front panel switches or an autoranging loop which uses the output of Z9 as the sense signal. Ranging occurs at 10% and 120% of full scale. The autoranging loop is described in detail in the Troubleshooting section, paragraph 5.7.1.9.

Signal front end configurations employing isolation are described under the appropriate options.

A power resistor, R36 and the diode circuit at the gate input of Q8 form an overload protection circuit capable of handling 500V rms on any range.

4.2.2 Signal AC Filter (Schematic Figure 7.2b)

Analog filtering of the AC signal is accomplished by the two pole active filter made up of Z10 and its associated resistors and capacitors.

As will be shown later, most of the effective filtering will be done in the chopping (demodulating) section. The chief filtering requirement is the attenuation of the 5th harmonic of the input. The actual filter attenuation of the 5th harmonic is roughly 14 db.

The AC voltage gain of the filter is approximately 7.3.

Since there is a phase shift in this filter (roughly +140°) and any phase difference between signal and reference channels is a source of error, an identical filter is placed in the reference channel (Z18).

In a multi-frequency instrument (Model 225) one set of AC filters is on the Main Board (usually 400Hz). Additional sets of filters are contained in the Frequency plug-in cards and are switched in corresponding to the Front Panel or Remote Control Frequency Select.

4.2.3 Signal Channel Demodulators (Schematic Figure 7.2c)

As has been mentioned, the key process in phase-sensitive instrumentation is demodulation (alternately shown as multipli-

cation, detection, chopping, etc.) whereby DC voltages proportional to the In-Phase and Quadrature components of the SIGnal input are generated.

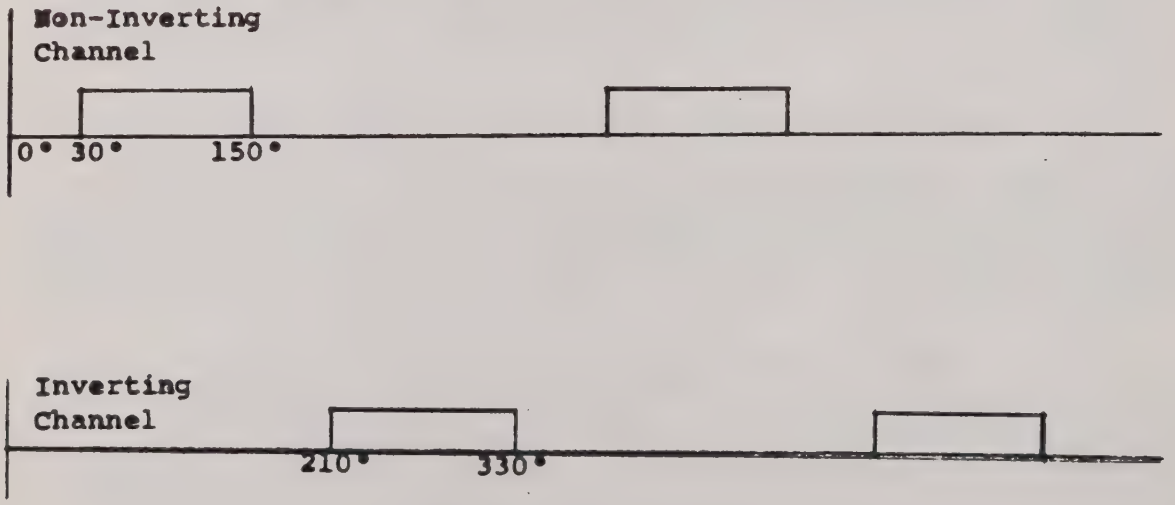
The IN-PHASE demodulator is made up of two shunt switching transistors. Q13 demodulates the AC signal coming directly from the AC filter output (TP2) and Q12 demodulates the inverted AC filter output, thus implementing a full-wave demodulator.

The equivalent takes place in the Quadrature channel where Q15 and Q14 are the switching transistors.

The signals operating the switching transistors are referred to as $\pi/6$ signals because of their waveshapes and duty cycles. Their general shape is shown in Figure 4.3.

The switching signals operating the In-Phase channel are in-phase with the output of the Signal channel AC filter (TP2). Those operating the Quadrature channel are 90° out of phase with TP2 voltage. These switching waveforms are derived from the $\pi/6$ Generator (Figure 7.2f) portion of the phase lock loop and are fed to the demodulators through Z6.

The resultant signals are fed to the DC filters.



$\pi/6$ Chopping Waveform

FIGURE 4.3

4.2.4 Signal Channel DC Filters (Schematic Figure 7.2c)

The In-Phase DC filter is made up of Z14 and Z15 and associated resistors and capacitors to form a three-pole Bessel filter (fastest rise time filter configuration).

The Quadrature DC filter is made up of Z16 and Z17 stages. Their full scale output is 8.75VDC which goes to the A/D Board for conversion.

The second stage of the In-Phase filter (Z15) is also used in the TOTAL mode, switching by means of Q16 and Q17.

4.2.5 TOTAL Mode Rectifier (Schematic Figure 7.2b)

The Op-Amp rectifier, made up of Z11 and associated circuitry, converts the signal from Z9 output to a proportional DC voltage.

Z12 is a single pole filter which feeds into the second stage of the signal channel DC Filter, Z15 through a switch, Q17.

This TOTAL mode, rectified voltage is a measure of the combined effects of all components in the AC signal, i.e., FUNDamental, noise and harmonics.

4.2.6 Reference AGC (Schematic Figure 7.2e)

The function of this section is to deliver a constant amplitude, zero phase shifted reference signal to the phase lock loop, independent of REFerence input amplitude variations between 0.2V and 200V rms.

To achieve this, with very low phase shift variations over the frequency range, a combination of a relay-controlled RC attenuator and a photocell attenuator is used.

Regarding the RC attenuator before Q41 with the relay (K7) open, the input attenuation is 0.157. This condition corresponds to inputs between 0.2V and roughly 6.3V rms.

With K7 closed, the attenuation is increased to 0.00506. This condition corresponds to inputs between 6.3V and 200V rms roughly. NOTE: Using this configuration eliminates the need for protection circuitry since a high impedance (R212) is always in series with the input.

Q41 and Q42 make up the high impedance FET amplifier which feeds the photocell attenuator made up of R222 and V1. The AC voltage on the photocell is stabilized by the feedback control loop made up of Z46, Z47 and Q47 driving the bulb of the photocell.

Z44 is a high impedance buffer amplifier which feeds the phase lock loop and the AGC feedback loop. Z44 output is rectified by Z47 and fed to Z46 which performs integration and servo compensation. Z46 drives Q47, which drives the bulb to close the loop.

The AC level is set by R232, producing an offset current into the integrator. The loop will adjust the output AC level so the DC current from the rectifier equals this offset current.

Thus, if the input level increases, the voltage across the photocell will tend to increase as will the DC current from the rectifier. This produces a difference current into the integrator which will increase the voltage on the bulb, decrease the resistance of the cell and lower the output voltage so as to produce zero difference current. This new output voltage, of course, is the same as before, hence AGC.

Instead of a separate control loop around the input relay, the same photocell control loop, acting through a slow hysteresis circuit, Z45, operates the relay.

The behavior is as follows: Assuming the input is at 4V rms, the relay is out and the photocell loop is in its normal operating range, the reference input level is then increased to 115V rms, and the photocell loop will increase cell attenuation until the voltage on the bulb saturates at 5V DC. This is not enough attenuation, so there is a difference current into the integrator which makes its output ramp up toward + saturation.

However, hysteresis circuit Z45 is set to trip at roughly 9V and when this level is reached (delayed by low pass filter C133), Z45 output goes from negative to positive saturation, bringing in relay K7.

This attenuates the signal so as to bring it into the control range of the photocell loop. The filtering in the hysteresis circuit is to eliminate oscillation due to transients generated at switching times.

A similar behavior results when the relay is in, and the input voltage is lowered. The integrator goes negative, trips Z45 and the relay drops out, raising the AC voltage to a level within the control range of the photocell loop. The NO SYNC warning light is activated by the circuitry of Z48, Z50 and Q52. Z48 is an Op-Amp used as a strobed comparator. The processed reference voltage at Z47, pin 6 is sampled at Z48 by a pulse derived from the phase-locked loop. When the 0V pulse arrives, the voltage from Z47, pin 6 will be negative if the loop is in lock. If it is not, Z47, pin 6 voltage will be positive when the pulse occurs and a positive pulse will appear at Z48, pin 6, triggering Z50 single shot and turning Q52 and NO SYNC light on. The single shot will be retriggered until the phase lock loop is synchronized to the reference voltage.

4.2.7 Reference Phase Lock Loop, $\pi/6$ Chop (Schematic Figure 7.2.e)

The sole function of the Reference Phase-lock loop is to provide 0° and 90° chopping signals for the signal channel demodulators.

As mentioned, the advantages of this approach are:

1. Allows the use of a $\pi/6$ chopping waveform over the ±5% bandwidth, providing filtering.

2. Ease of generating a substantially error free 90° chopping signal over the ±5% bandwidth.

Referring to Figure 4.4, the reference input to the loop passes through the AC filter (Z18) which is identical to that in the signal channel. The signal level out of the filter is about 4.6V peak-to-peak.

The full-wave demodulator is identical to those in the signal channel, two shunt choppers (Q27 and Q30) and an inverter (Z19).

The pertinent output of the demodulator is a DC current into the integrator (Z7) which drives the Voltage Controlled Oscillator (Q31 and Q32), feeding a pulse train into the $\pi/6$ chopper. This pulse train is 12 times the frequency of the reference.

By a process of counting and gating, the $\pi/6$ chopper generates the proper waveforms which feed the demodulator and thus closes the feedback loop.

If the reference sinusoidal input is represented as Er sin ωt (disregarding the balanced phase shift through the AC filter) and the chopping waveform as cos $(\omega t + \sigma)$, where σ is a phase error, then the error current into the integrator is:

$$E = K1 \sin \sigma + K2 \sin (2\omega t + \sigma)$$

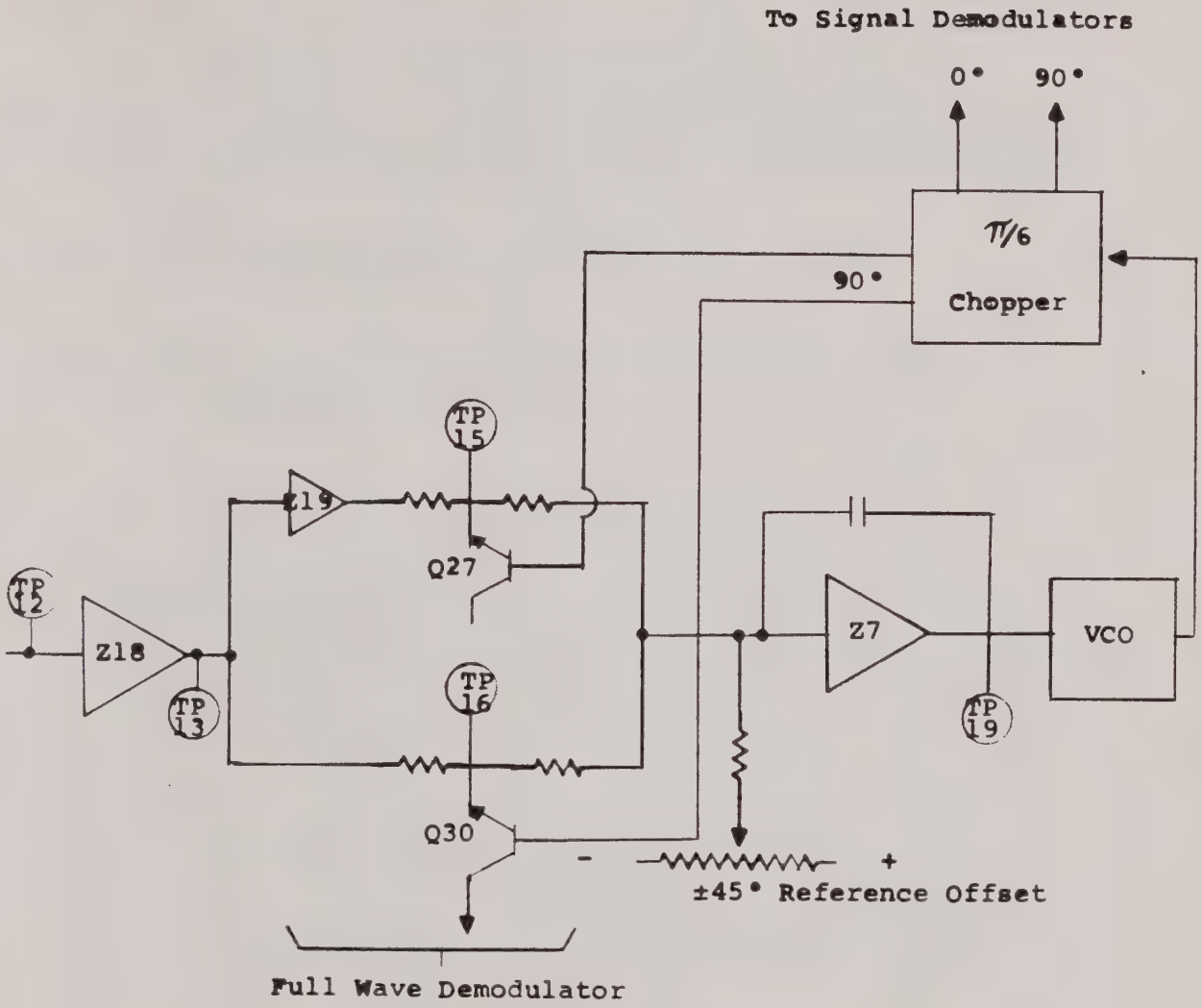
The AC term is filtered by the integrator.

Since the VCO generates a pulse rate output for a constant DC input, it behaves as an integrator also.

Thus the loop is a second order (double integration) feedback control system providing zero position error for a rate input.

The phase lock loop rate input is cycles or radians per second, i.e., frequency. The zero position error corresponds to zero phase difference between the input sinusoidal voltage and the chopping signals.

Therefore the loop will drive itself until $\sin \sigma = 0$ or $\sigma = 0°$ corresponding to a constant DC voltage into the VCO, and zero error current into the Op-Amp integrator. The chopping signals are phase-locked to the reference input.



Reference Phase Lock Loop

FIGURE 4.4

4.2.8 ±45° Reference Offset (Schematic 7.2.e)

Since the phase lock loop settles to a state of zero current into the integrator, if an offset current is injected into the integrator, and equal and opposite current will be generated by the demodulator.

This demodulator current is the result of a phase difference between the reference sinusoid and the chopping signals.

This phase offset covers a range of ±45° and is controlled by a front panel potentiometer (R134). The amount of phase offset can be read on the display in the REFERENCE PHASE mode.

4.2.9 Fundamental Frequency Operation

The DPAV used in FUNDamental frequency mode reads the total magnitude of the fundamental component (E_1) of the selected frequency by making a phase sensitive measurement using the signal as the reference. The phase angle θ is therefore equal to 0°. This is accomplished by using the signal voltage output of Z11 as the reference voltage. Z11 is the TOTAL mode rectifier and its output at pin 6 is equivalent to the SIGnal input amplified by an open loop amplifier, i.e., the signal here is a square wave in-phase with the signal input at the input signal terminals of the DPAV. Thus the angle θ is 0°. This signal is switched into the REFerence channel in the FUNDamental mode by means of FET Q43, Q45 and Q46. This operation occurs when Q45 and Q46 are opened (thus disconnecting the input reference) and Q43 is closed. See Figure 7.2e (8E). This feeds the signal into the reference amplifier Z44. Thus the phase angle between the signal and this derived reference is 0°. Looking at Figure 4.1, we now have the equation

$$E_1 = \sqrt{E_1^2 \cos^2 \theta + E_1^2 \sin^2 \theta}$$

substituting θ = 0°, we get

$$E_1 = \sqrt{E_1^2 (1)^2 + E_1^2 (0)} = \sqrt{E_1^2} = E_1$$

The operation of the DPAV is then the same as if it were reading an in-phase voltage with θ = 0°. The active filtering and the $\pi/6$ generator are thus used to provide an accurate reading of the fundamental frequency voltage.

4.3 FREQUENCY CARD DESCRIPTION (Schematic Figure 7.5)

The Model 225 components for one frequency (usually 400Hz) are on the Main Board and the others on a plug-in card (one card per frequency). The signal processing is the same as that described in 4.2. The card contains:

1) Signal and Reference AC Filters

2) Phase lock loop demodulator, compensation and VCO

3) Enable-disable switches

4.4 ANALOG TO DIGITAL CONVERTER AND READ-OUT

The lower Main Board can, in general terms, be described as an AC to DC voltage converter where TOTAL, FUNDamental. IN-PHASE and QUADrature components of the AC signal are converted to DC. The function of the A/D converter and Read-out Section is:

1) To digitize and display DC voltages

2) To compute and display phase shift in degrees, using IN-PHASE and QUADrature voltages

3) To provide digital output signals for the digital interface card when this option is present.

The A/D Board is a horizontal board located at the top front of the unit and contains analog voltage processing circuitry and part of the digitizing circuitry.

The remaining digitizing circuitry is contained on the Read-out Board along with the Beckman Displays and the display bulbs.

A single ribbon cable, J4, connects the Main Board to the A/D Board. The Read-out Board is connected to the A/D Board by two ribbon cables, J1 and J2. For the Remote Control and Digital Output Option (03), two ribbon cables (J3 and J5) connect the A/D Board to the Remote Control/Digital Output card mounted to the rear panel.

4.4.1 DC Analog Voltage Processing (Schematic Figure 7.3)

Figure 4.5 is a block diagram of the front end of the A/D converter. The In-Phase and Quadrature DC voltages come from the Main Board (see Figure 7.2c) through J4 ribbon cable.

4.4.1.1 Absolute Value Amplifiers

The Quadrature voltage is fed to an absolute value amplifier made up of Z35 and Z36. When this voltage is negative, diode CR26 is back-biased and the amplification is through Z36, yielding a positive voltage at TP10. The nominal full range voltage at TP12 and TP13 is 8.75VDC and Z36 stage gain is nominally 1.09, yielding +9.5VDC at TP10.

With a positive input voltage, diode CR26 is forward-biased and the negative output of Z35 applied to Z36 through R129. Since R129 is one half the value of R136, the gain to the negative input is twice that from the positive input at TP12. This results again in a positive output at TP10, producing the action of an absolute value amplifier.

The polarity of the Quadrature voltage is sensed by transistor Q30 and gates of Z26 and Z40. Referring to the schematic of Figure 7.3, Z40 pin 3 is labeled "S" (for sine θ channel polarity) and is at a logic "1" when the Quadrature voltage is positive. This polarity information is fed to Z10 controlling the polarity display and also to the logic in the area of Z1 and Z2 which controls the counters in the ANGLE modes.

The TOTAL, FUNDamental or IN-PHASE voltage is fed from the Main Board to TP13 on the A/D Board, depending on the mode of operation. The absolute value ampli-

fier made up of Z37 and Z38 operates the same as the Quadrature channel. Polarity information is generated by Q29 and Z26 pin 11 and is fed to Z2 and Z6 to control polarity display and the counters in the ANGLE mode. Z26 pin 12 (TP16) is labeled "C" (for cos θ channel) and is at logic "1" when the In-Phase voltage is positive.

Relay K1 feeds the appropriate absolute value amplifier output to TP9 to be digitized. In the ANGLE modes, relays K1 and K2 apply the true In-Phase and Quadrature or the complement to the $\frac{\sin \theta}{\theta}$ generator and TP9, depending on which segment in 360° the phase angle resides..

4.4.1.2 Octant Detector

In the ANGLE modes, during a portion of the digitizing cycle, the counters are loaded with either 0.0°, 90.0°, 180.0°, 270.0° or 360.0° and are commanded to count either up or down. The control logic for this operation is located in sections (A9) and B9) of the schematic of Figure 7.3.

Each of the eight octants in the circle has a different command and is identified by the In-Phase polarity, Quadrature polarity and the voltage from an Octant Detector Z34. This Op-Amp stage simply determines whether the In-Phase voltage exceeds the Quadrature voltage or vice versa (Q28 provides hysteresis). The logic output at Z26 pin 6 is designated "OD" and is at a logic "1" level when the In-Phase voltage is greater than the Quadrature voltage.

4.4.1.3 Segment Detectors

The $\frac{\sin \theta}{\theta}$ voltage used in the ANGLE computation (designated TAN^{-1}GO^{TM} angle computation) is generated by Z27 and Z28. The effect of Z28 on the $\frac{\sin \theta}{\theta}$ voltage is controlled by relays K3 and K4, which are controlled by the segment detectors Z30 and Z31.

Referring to Figure 7.3, for an input phase angle in the first octant, for example, relays K1 and K2 will be shown as feeding the Quadrature voltage (sin θ) to TP9. The resistor dividers in front of Z30 and Z31 are such

as to cause relays K3 and K4 to be de-energized if the phase angle is less than 23°. If the phase angle is between 23° and 35°, relay K3 is energized and K4 de-energized. If it is between 35° and 45°, both K3 and K4 are energized. Q24 and Q25 provide hysteresis around the threshold angles.

Z26 pin 3 energizes the relays in the voltage modes and when the unit is out of sync.

4.4.1.4 DC Reference Voltage

The DC voltage standard is a temperature-compensated zener diode CR12 buffered by the non-inverting amplifier Z9 (location E4 in Figure 7.3). The nominal voltage at TP7 is -9.5VDC and is adjustable by trimpot R68.

The DC voltages at TP7, TP8 and TP9 are fed to the digitizer through switches Q11, Q9 and Q10, respectively.

4.4.2 Phase Angle Digitizing

The conversion of the In-Phase and Quadrature DC voltages to degrees phase angle in digital form is accomplished by a combination of analog to digital signal processing.

The technique for this A/D conversion uses a time-interval ratio measuring scheme with its attendant simplicity and accuracy, but in a new and unique way (Patent Pending). It is essentially a DC resolver-to-digital converter, the resolver data being the In-Phase and Quadrature components of the signal input ($TAN^{-1}GO^{TM}$ angle computation).

The analog-to-digital conversion is accomplished by the system shown on the block diagram, Figure 4.6. Typical waveforms are shown in Figure 4.7.

During a fixed time To, the input is switched to +V1 (TP9), which is proportional in this mode to the QUAD voltage, sin θ. Thus the ramp voltage at To is proportional to To sin θ. At To the input is switched to -V2, which is proportional in this mode to a synthesized voltage $\frac{\sin \theta}{\theta}$ (TP8) which ramps V1 (t) back to 0V.

Thus the following equation is implemented:

$$V1\ (To) = \frac{(\sin \theta)\ To}{RC} = \frac{(\sin \theta/\theta)Tm}{RC}$$

$$\text{or } Tm = \left(\frac{\sin \theta}{\sin \theta/\theta}\right)To = (\theta)\ To$$

i.e., Tm is directly proportional to the angle in radians

The conversion of radians to degrees is accomplished by means of a scale factor adjustment of the $\frac{\sin \theta}{\theta}$ Generator (Z27) and a factor of 20 clock frequency reduction during the Tm portion of the ramp cycling. This is implemented by the signal at Z15 pin 4 (section E14 in Figure 7.3) which enables the low frequency signal generated by Z17 and Z18 counters.

To and Tm are quanitized in the form of pulses from the clock. The known time To is generated by accumulating 10,000 pulses in the four-stage counter, starting from a zero reset state. When the 10,000th pulse is sensed, the input is switched from +V1 to -V2, which ramps V1 (t) back to zero volts. Z13, pins 3 and 6, is a set/reset flip-flop controlling the switching of +V and -V2.

The Zero Crossover Detector (Z23) senses 0V and does the following:

1. Strobes (TP3) the accumulated pulses (Tm) into the latch memory for display.

2. Generates a reset pulse (TP2), delayed from the strobe pulse, which resets the counter to zero.

3. Switches the input back to V1 and the cycle repeats.

Since the voltage $\frac{\sin \theta}{\theta}$ is not available in an exact form, an approximation is synthesized, using the sin θ and cos θ DC voltages.

At small angles, the cos θ approaches $\frac{\sin \theta}{\theta}$ and as θ increases, cos θ becomes smaller than $\frac{\sin \theta}{\theta}$. To compensate for this, a portion of the sin θ voltage is added to the cos θ voltage to bring it toward sin θ/θ. Thus,

$$\left.\frac{\sin \theta}{\theta}\right|_{app.} = a \sin \theta + b \cos \theta$$

As θ increases, the values of the coefficients "a" and "b" must change to maintain accuracy. The final design covers a total range of 45° broken into 3 segments, i.e., there are 3 different values for "a" and "b", depending on the particular segment within the 45°. The first segment covers 0 to 23°, the second 23° to 35° and the third 35° to 45°. The segment detectors shown in Figure 4.5 determine which segment the input angle is in and makes appropriate changes in the $\frac{\sin \theta}{\theta}$ generator.

Since the approximation of $\frac{\sin \theta}{\theta}$ is used only over a 45° internal, (excessive errors beyond 45°) in the second octant (45° to 90°) the following applies:

(a) IN-PHASE and QUAD voltages are interchanged to implement the complementary function.

(b) At the end of the fixed period of ramping (To) 90.0° is loaded into the counters.

(c) The counters are placed in a count-down mode.

For example, if the input angle is 80°, the true IN-PHASE is 0.1737 and the true QUAD is 0.9848. These are reversed into the $\frac{\sin \theta}{\theta}$ generator and the A/D converter which processes the equivalent of 10°. However, due to the 90.0° counter preset and the count-down command, the read-out will be 80.0°, the correct value.

Table 4.1 gives the configuration for each octant.

TABLE 4.1

ANGLE MODE COUNTER CONTROL

OCTANT	COUNTER LOAD	COUNT	FUNCTION
0-45°	0.0°	Up	Normal
45-90°	90.0°	Down	Complement
90-135°	90.0°	Up	Normal
135-180°	180.0°	Down	Complement
180-225°	180.0°	Up	Normal
225-270°	270.0°	Down	Complement
270-315°	270.0°	Up	Normal
315-360°	360.0°	Down	Complement

4.4.3 Voltage Digitizing

The digitizing of the DC voltages is accomplished by using the same techniques described above (see Figures 4.6, 4.7 and 7.3).

During fixed time To, the input is switched to +V1 (TP9), which is proportional in this mode to the unknown DC voltage Va (TOTAL, FUND, IN-PHASE or QUAD).

At the end of the To interval, the input is switched to a precision reference voltage -Vref (TP7), which ramps V3 (TP5) voltage back to zero where the data is strobed out at zero crossover and the cycle repeats.

Thus the following equation is implemented:

$$V1\ (To) = \frac{Va\ To}{RC} = \frac{Vref\ Tm}{RC}$$

$$\text{or } Tm = \frac{Va}{Vref}\ To$$

and since To and Vref are known quantities, Tm is directly proportional to the unknown voltage Va.

Where the input voltage to be digitized exceeds a full range value (10,000 pulses) a spillover pulse is generated at Z13 pin 11. This pulse is fed through Z12 latch to Z11 latch, which feeds the "1/2 Digit" drive circuitry on the Read-out Board through J1 pin 11.

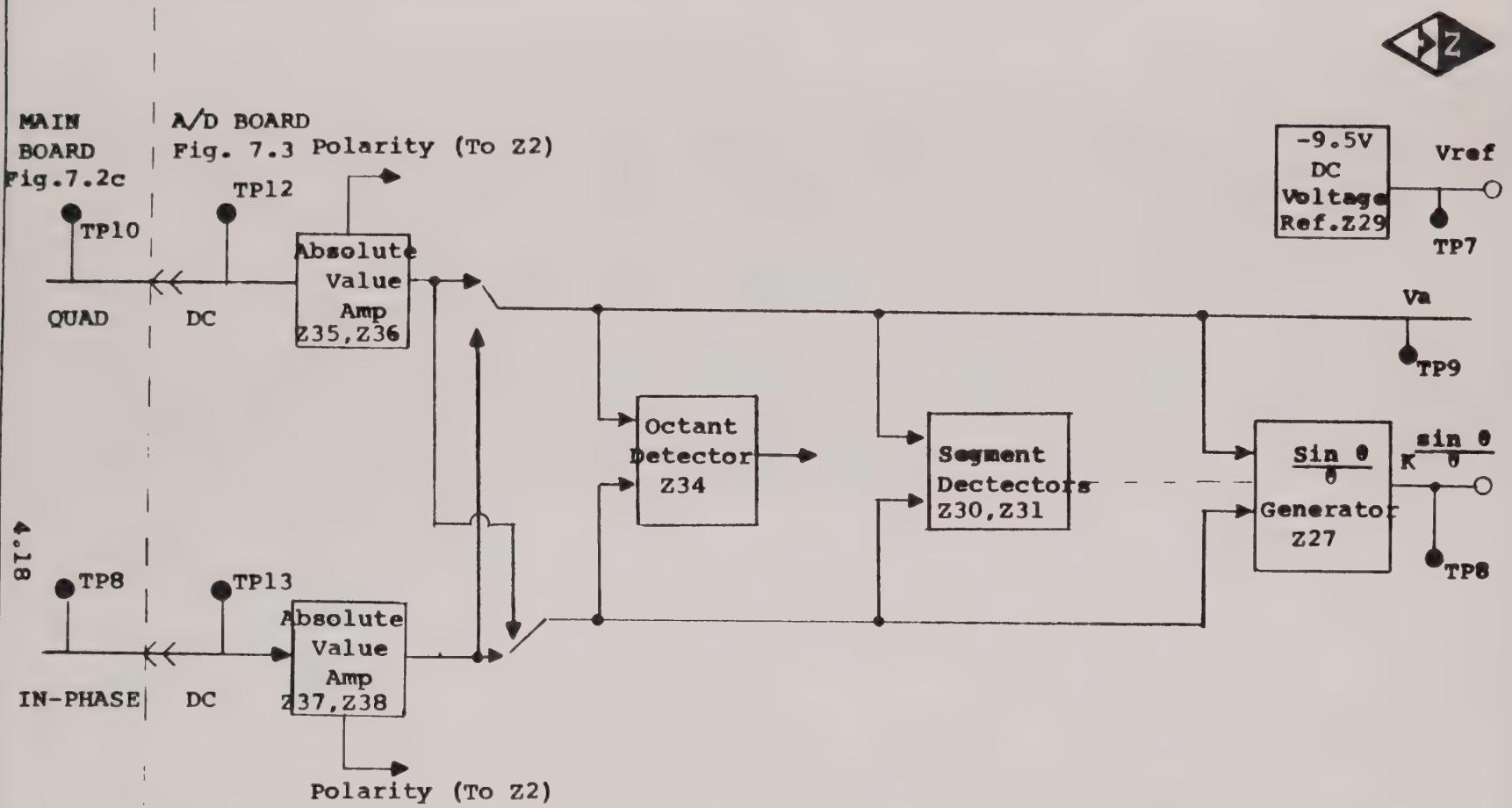
The delayed waveform generated at Z12 pin 6 is used to disable the spillover pulse that occurs at the end of the fixed time period from lighting the "1/2 Digit" read-out.

4.4.4 Read-Out Board

The Read-out Board contains the display devices and digital circuitry used in the digitizer.

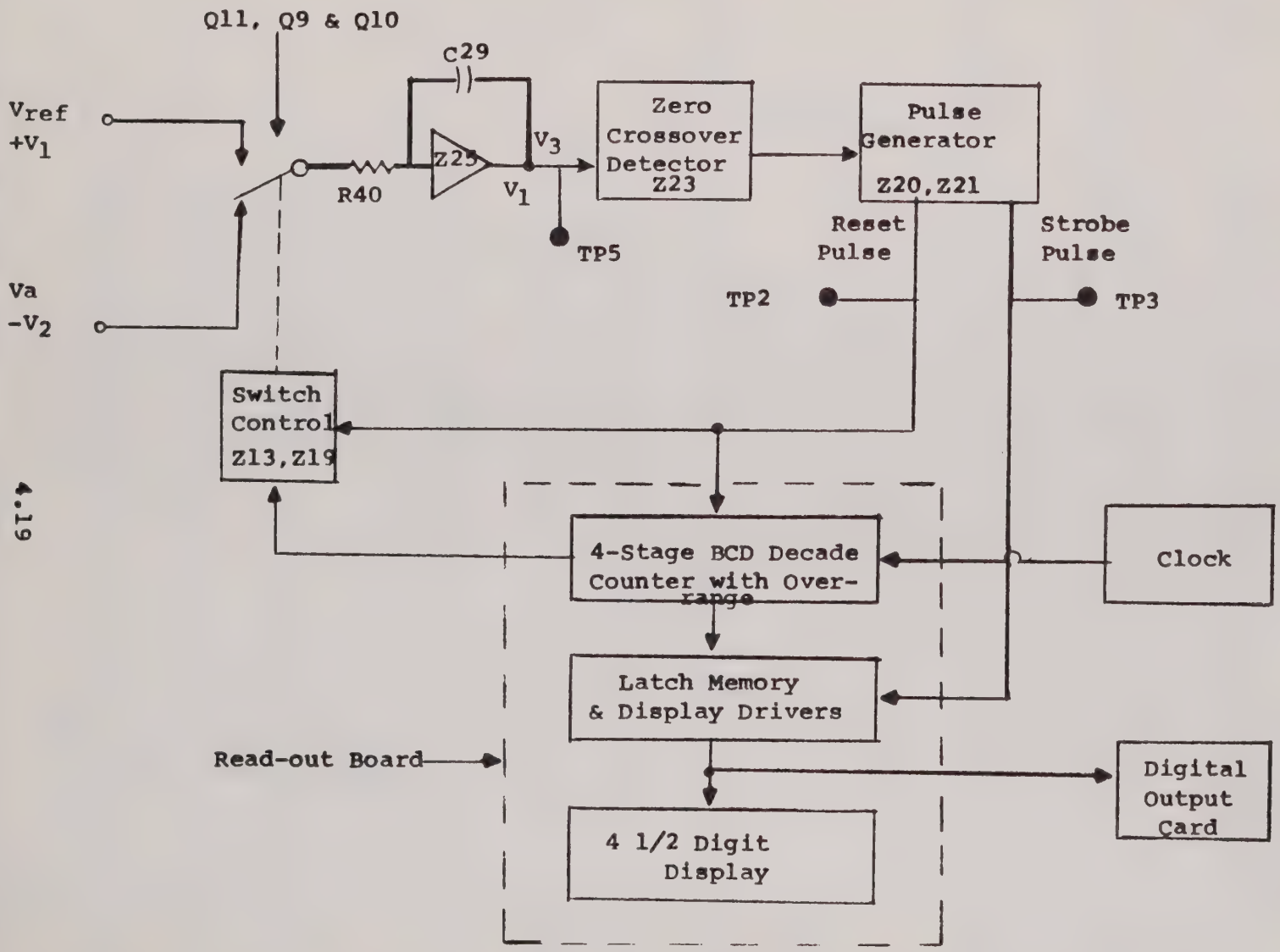
Figure 4.6 shows the block diagram of the digitizer loop indicating the circuitry on the Read-out Board.

Referring to the schematic of Figure 7.4, the clock pulses (up or down) are applied to the first BCD counter Z12 representing



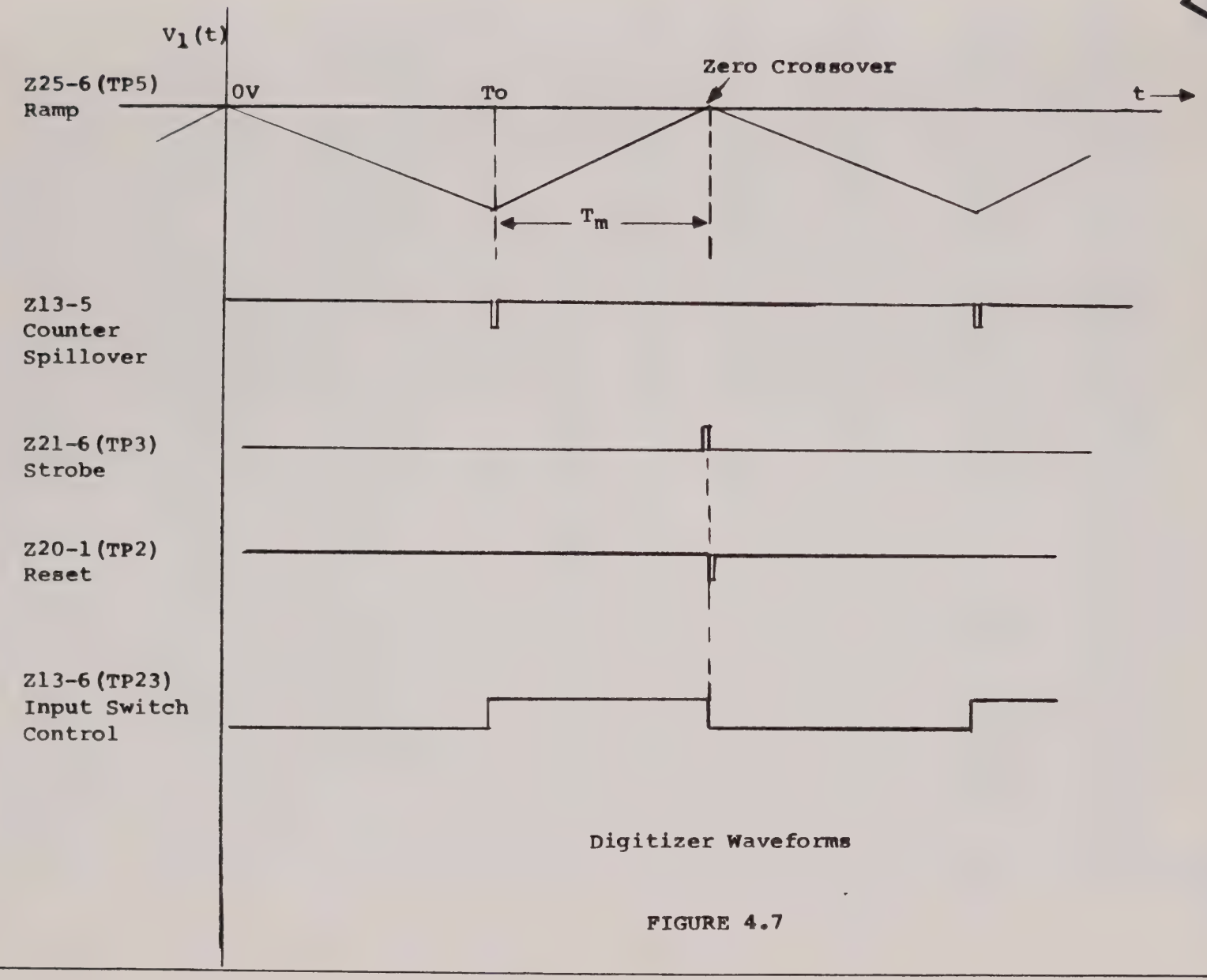
A/D Converter Analog
Signal Processing

FIGURE 4.5



A/D Converter Block Diagram

FIGURE 4.6



Digitizer Waveforms

FIGURE 4.7

the least significant digit. Z8 is a 4 bit latch which stores the digital word in Z12 counter at strobe time. This 4 bit BCD number is fed to Z4 decoder-driver of the gas discharge displays.

The count from Z12 spills to Z11, Z10 and finally to the most significant digit (MSD) Z9. The latches, decoder-drivers and associated displays operate in a fashion identical to that described for Z12.

At the 10,000th pulse, Z9 pin 7 goes from logic "1" to 0 and is fed out to J1 pin 10 as a spillover to signal the end of the fixed time To, or to enable the over-range 1/2 Digit through Z12 and Z11 on the A/D Board.

Q1 operates the over-range digit. Q2 operates the "tens" Digit, Q3 operates the "hundreds" Digit and Q4 operates the "thousands" Digit.

Indicator bulbs and driver chip Z13 are also shown in Figure 7.4.

4.5 REMOTE CONTROL/DIGITAL OUTPUT (OPTION 03)

This option card is mounted to the rear panel and is interconnected to the unit with ribbon cables and a single jumper. The interface is through two rear panel connectors.

Signal levels and coding are described in the specification section. Figure 7.6 is a schematic of the card showing appropriate labeling to facilitate troubleshooting. The input/output coding and data output are straightforward. The Data Request/Ready circuitry is more involved and warrants some explanation.

A positive Data Request pulse at J1, pin 13, sets Z10 latch (pins 3 and 6). This transmits an enable signal through some delay gating to Z15 single shot, which generates a 2.5 second pulse, the trailing edge of which is the Data Ready flag (J2, pin 11). This trailing edge, through Z12, pin 3, resets Z10 latch.

If the unit is in TOTAL mode and in a state of overload, Z14 single shot is enabled and will start its delay pulse when the unit comes out of overload by generating a negative pulse at Z14, pin 1. This delay is set at approximately 6 seconds since the recovery from overload in the TOTAL mode is longer than in the other modes.

If the unit is still ranging after the Data Request pulse is received, a pulse train at Z13, pin 3 will keep retriggering Z15 single shot so that the Data Ready flag will be delayed until the unit has stopped ranging and has had time to settle to a stable reading.

The overload signal coming in at J3, pin 12 is a switching voltage, changing between a logic "0" and "1". It is fed to Z15 single shot, retriggering it and delaying the Data Ready flag until the unit is out of overload and a stable reading achieved.

The sync signal coming in at J3, pin 13 is normally at a logic "1" enabling the Data Request signal at Z10, pin 10 through to Z15 single shot. If the unit is out of sync, Z10, pin 9 will be low, disabling the Data Request signal to Z15 until a sync condition is reached, at which time the Z15 single shot starts its pulse.

4.6 NULL METER CIRCUIT DESCRIPTION (Option 10)

Operation can be followed by using the schematic of the null circuit. The DC voltage corresponding to QUADrature and IN-PHASE voltages are connected to the drains of Q1 and Q2. The QUADrature signal is taken from E68 of the main board and the IN-PHASE voltage from E70 of the main board (see Figure 7.2c in the manual).

When the mode switches are set to read TOTAL, FUNDamental or IN-PHASE voltage, digital inputs $\overline{Q}$ and $\overline{RP}$ are true (1) and digital input θ is false (0). Going through the logic, we have pin 3 of Z3 true (1), thus pin 6 of Z3 is false (0) and pin 8 of Z3 true (1). This in turn makes pins 2 and 4 of Z1 true. By following the schematic, it is easily seen that if $\overline{RP}$ is false (0), as it is when reference phase is read, or θ is true (1), as it is when the phase angle is read, the inputs of Z1, namely pins 2 and 4 are false and thus these gates are disabled since a null meter has no function in such modes. Now, looking at $\overline{Q}$ it is false (0) when TOTAL FUNDamental or IN-PHASE is being read, thus pin 3 of Z1 goes high and enables the gate of the IN-PHASE FET, Q2 thrugh Q4, to turn on, allowing the IN-PHASE voltage to the 741 amplifier (Z2).

On the other hand, if $\overline{Q}$ is true (1), i.e., if the QUADrature button is pressed, pin 3 of Z1 goes false (0) and pin 11 of Z3 goes false (0) also, causing pin 6 of Z1 to go high, which allows FET Q1 to go on through Q3. This in turn connects the QUADrature signal to the 741 amplifier (Z2).

R1 is an offset adjustment pot which makes it possible to adjust the meter to its center null position when the IN-PHASE and QUADrature voltages are disabled, i.e. by selecting phase angle or reference phase modes. R3 is the meter calibration adjustment for the current around the meter so that it can be adjusted for full scale deflection. The two diodes in the 741 amplifier feedback loop allow the meter to be more sensitive to null condition than at full scale. When near the null condition, these diodes will conduct little, thus more of the feedback current appears across the meter. At higher levels, more current is conducted through these diodes and less through the meter, thereby giving less sensitivity to the meter.

SECTION V
MAINTENANCE

CAUTION: HIGH VOLTAGES EXIST AT SEVERAL POINTS IN THIS INSTRUMENT. NORMAL PRECAUTIONS CONSISTENT WITH GOOD PRACTICE SHOULD BE TAKEN TO REDUCE SHOCK HAZARD.

A potential shock hazard exists when the unit is operated with ungrounded power source or case. Operators of this instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to persons or property in the process of, or as a result of, maintenance, calibration or setting up the instrument.

5.1 INTRODUCTION

This section contains instructions for the general maintenance of the DPAV. Procedures for performance testing (5.5), basic alignment (5.8), complete alignment (5.6) and troubleshooting (5.7) are included.

An accuracy calibration should be made at three-month and a full performance evaluation and alignment at six-month intervals.

For convenience, 400Hz is described as the Main Board frequency. If a frequency other than 400Hz is on the Main Board, that is the one referred to.

Functional checks can be made immediately after turn-on, but accuracy checks and alignment should be made after one-half hour warm-up at room temperature with covers on. In final calibration, the top cover may be removed after warm-up and the unit adjusted as quickly as possible without changing the thermal equilibrium excessively.

5.2 REMOVAL OF COMPONENTS

During troubleshooting it may become necessary to remove a component from its socket or a ribbon cable from its connector. Use extraction tools to minimize the possibility of damage. For dual-in-line IC packages, Augat tool No. T114-1 is recommended. For the ribbon cable, 3M tool No. 3438 is supplied.

When removing a component soldered to a board or unsoldering a wire, follow precautions consistent with good manufacturing practice.

5.3 REPLACEMENT OF FUSE

The power line fuse is located on the rear panel. It can be replaced by removing the fuseholder cap. For 115VAC line operation, the fuse is a 0.5A Slo-Blo, Type 3AG; for 230VAC, a 0.25A Slo-Blo, Type 3AG.

5.4 TEST EQUIPMENT REQUIRED

5.4.1 Variable, low distortion signal source, 10Hz-100kHz, e.g., Krohn-Hite Model 446R or Weston Model DVO-102 or equivalent.

5.4.2 Variable oscillator, Hewlett Packard Model 200CD or equivalent.

5.4.3 Power Amplifier, e.g., Krohn-Hite Model DCA-10R or equivalent.

5.4.4 AC Standard: Fluke Model 5200A or 510A, or equivalent.

5.4.5 Oscilloscope: Tektronix Model 422 or equivalent.

5.4.6 DC Meter., e.g., Fluke Model 895A or equivalent.

5.4.7 Two Ratio Boxes, e.g., NAI Model RB-504 or equivalent.

5.4.8 High Frequency Ratio Box, e.g., Dytronics Model RT-501 (for frequencies above 5kHz) or equivalent.

5.4.9 Phase Generator, e.g., Exact Electronics Model 337 or equivalent (see paragraph 5.5.3.1).

5.4.10 V.O.M., e.g., Simpson Model 260 or equivalent.

5.5 PERFORMANCE CHECKS

Use the following procedures to verify proper operation and accuracy of the instrument and also for incoming inspection or for periodic calibration. Accuracy limits are, in general, tighter than specifications and may not necessarily be cause for rejection. Readings outside these limits may indicate need for calibration only to insure optimal performance.

Consult the Alignment and Calibration (5.8, Basic and 5.6, Complete Calibration) and/or Troubleshooting Sections if a component fails or a reading is out of specification.

5.5.1 Functional Checks

5.5.1.1 Ground Isolation Check:

For non-isolated units, remove rear panel ground link and check for open circuit between chassis and input low terminal.

For Broadband Isolation Option check for open circuit between signal low and chassis, and reference low and chassis.

For Transformer Isolation Option remove rear panel ground link and check for open circuit between signal low terminal and chassis with TRANSformer button pushed and also with DIRect button pushed.

5.5.1.2 Preliminary Checks:

(a) With unit in TOTAL mode, apply 100V RMS at 400Hz to REFerence input. If unit does not contain 400Hz, apply the frequency corresponding to that on the Main Board (other frequencies will be on the plug-in cards). Select same frequency pushbutton and short signal input.

(b) Press function switches through all modes from TOTAL to REF PHASE and note correspondinb bulb light in the display window. Return to TOTAL mode.

(c) Press IN button under REFerence OFFSET and note REF OFFSET bulb light. Press OUT.

(d) Press range buttons from 10mV to 500V and check that decimal point and the V, MV light correspond to selected range.

(e) With unit in IN-PHASE mode and 100V applied to REFerence input, vary the frequency ±5%. The NO SYNC light should remain off. Vary the frequency ±10% and observe the NO SYNC light goes on. Repeat at all frequencies. Return to 400Hz.

(f) With unit in IN-PHASE mode and 100V in REFerence input, place unit in AUTOrange. From a ratio box, apply a SIGnal

input from 0mV to 100V and note that the unit up-ranges at 120% ±3% of full scale and down-ranges at 10% ±0.3% of full scale. Note OVLD (overload) bulb goes on when 120% full scale is reached just before up-ranging occurs.

5.5.2 Voltage Accuracy Check (After one-half hour warm-up at room temperature)

5.5.2.1 Offset and Noise Check

(a) Apply 10V RMS, 400Hz REFerence signal, short the signal input and place unit in 1000mV range.

(b) TOTAL mode offset should read 1.0mV or less and IN-PHASE and QUAD modes should be less than or equal to the values given below:

FREQUENCY RANGE	OFFSET READING	
	1000mV Scale	10mV Scale
30Hz to 5kHz	0.4mV	0.004mV
5kHz to 20kHz	0.8mV	0.008mV
20kHz to 32kHz	1.2mV	0.012mV

(c) With unit in the 10mV scale, the TOTAL reading should be 0.035mV or less and the IN-PHASE and QUAD readings the same as in paragraph (b).

(d) With unit in FUND mode, 1000mV range, apply an in-range REFerence input and 8mV SIGnal input. Change input frequency from 400Hz to 500Hz for a few seconds and note that the NO SYNC light goes on. Return to 400Hz and the NO SYNC light should go off after a couple of seconds. If it does not, the phase lock loop needs alignment.

5.5.2.2 Accuracy and Linearity Checks

(a) Apply 10V RMS, 400Hz to REFerence input, place unit in 10mV range and apply 10mV RMS ±0.02% from AC Standard. (NOTE: Two ratio boxes should be used to develop 10mV in order to minimize attenuation errors.)

(b) Check that FUND and IN-PHASE readings are within specifications as shown below:

FUND, IN-PHASE and QUAD Mode Accuracy

30Hz to 60Hz	0.05% F.S. +0.1% reading
60Hz to 1.5kHz	0.05% F.S. +0.07% reading
1.5kHz to 20kHz	0.1% F.S. +0.15% reading
20kHz to 32kHz	0.15% F.S. +0.2% reading

(c) Repeat paragraphs (a) and (b) on each range up to the 500V range, changing signal ratio box for appropriate full scale reading.

(d) In the case of Transformer Isolation, paragraphs (a), (b) and (c) should be followed in both DIRect and TRANSformer mode.

(e) With a full scale SIGnal input, place unit in REFerence PHASE mode and dial in +45°. Place unit in FUND mode and check that it reads 1000.0 ± accuracy.

(f) Linearity Checks: With 10V RMS, 400Hz REFerence input, apply 1.0 ±0.02% to SIGnal input through a ratio box. Reduce the input in 0.2V steps to 0V and check that DPAV readings match ratio box settings within the accuracy specified for that frequency of operation (e.g., for 400Hz, accuracy is 0.05% of full scale +0.07% of reading).

(g) Apply 10V at 90° ±1° to REFerence input and place unit in QUAD mode and 1000mV range with 1V ±0.02% in SIGnal input. Check that the display reads within specification as shown in 5.5.2.2(b) and with negative polarity.

(h) Apply 10V at 270° ±1° to REFerence input and repeat (g) noting a positive polarity.

5.5.2.3 Frequency Card Checks

Repeat paragraphs 5.5.2.1 and 5.5.2.2 for each instrument frequency.

5.5.2.4 TOTAL Mode Frequency Response

(a) With unit in TOTAL mode, set range to 1000mV and apply 1.0V RMS ±0.05% to SIGnal input from variable frequency sources. Input amplitude should be monitored with AC Fluke meter if accurate variable frequency generator is not available.

(b) Sweep the frequency of the signal source from 30Hz to 100kHz and insure DPAV reads within spec (see 1.2.8.1).

(c) Repeat steps (a) and (b) with 10.0V input on 10V scale.

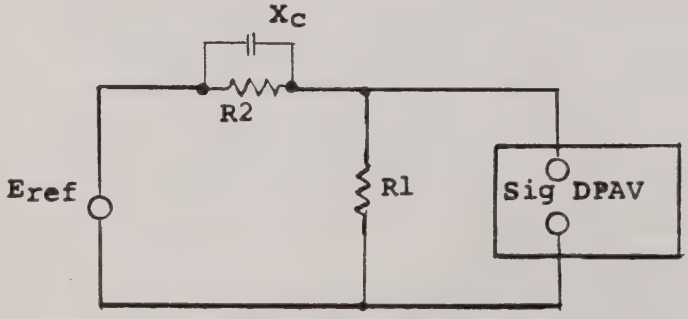
5.5.3 Phase Checks (After one-half hour warm-up at room temperature)

5.5.3.1 Phase Angle Generation

The PHASE ANGLE and REFerence PHASE modes require accurate phase shifted signals to verify performance. Some common approaches follow.

(a) Phase Generator should generate phase shift from 50Hz to 25.6kHz with accuracy of: 25-50Hz: 0.17°
50-100Hz: 0.12°
100Hz-1.4kHz: 0.07°
1.4kHz-25.6kHz: 0.11° +0.013f
(f in kHz)

(b) RC Passive Phase Shifter (Figure 5.1) can be constructed using the equations shown. Components should be high quality, stable parts such as metal film resistors and polystyrene capacitors and their values measured accurately.



RC Phase Shifter

Figure 5.1

$$\text{Attenuation} = \frac{R1}{(Z)}$$

$$\text{Phase Shift} = \tan^{-1}\ \frac{R2}{Xc}$$

if $R1 \ll (Z)$

$$Z = \frac{R1}{1 + j\frac{R2}{Xc}}$$

$$Z = \frac{R2Xc\ \sqrt{X^2c + R2^2}}{X_c^2 + R_2^2}$$

(c) Ratio Box Phase Shifter shown below requires an accurate 0° and 90° signal equal in amplitude and placed across the ratio box. The output amplitude will vary through a minimum of 0.707 of the 0° and 90° signal at 45°.

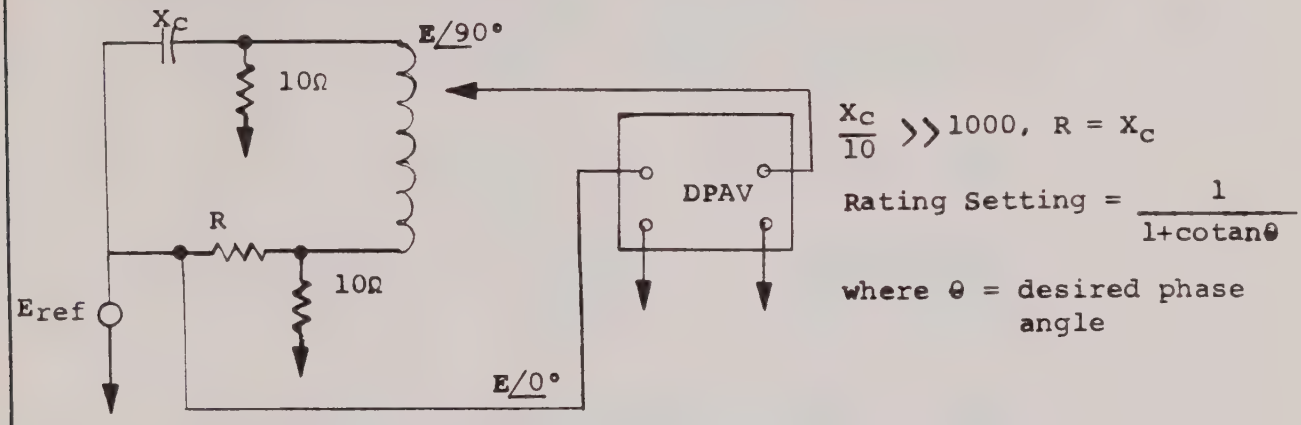


Figure 5.2. Ratio Box Phase Shifter

NOTE: A number of instruments on the market generate precise phase angles and can be used in this check-out. It is important to add to the DPAV angle spec the accuracy of the input phase angle.

5.5.3.2 Phase Match Check

(a) With unit in QUAD mode and 1000mV range, apply 10V to REFerence input and 1V ±1% at 0.0° to SIGnal input. Note reading. Apply short to signal input.

(b) Check that change in QUAD reading from 0V to FS is less than or equal to values below.

FREQUENCY RANGE	QUAD READING
30Hz to 60Hz	±2.4mV
60Hz to 5kHz	±1.4mV
5kHz to 20kHz	±2.8mV
20kHz to 32kHz	±4.0mV

5.5.3.3 Phase vs Reference Amplitude Check

(a) Place unit in QUAD mode, 1000mV range and apply 1000mV ±1% at 0° to SIGnal input.

(b) With REFerence input voltage set to approximately 3V, note reading on the display. Adjust REFerence level to 0.2V, 5.5V, 7V, 100V and 200V. Check that the peak change from the 3V level is equal to or less than the values below:

FREQUENCY RANGE	QUAD READING
30Hz to 60Hz	±0.6mV
60Hz to 5kHz	±1.0mV
5kHz to 20kHz	±1.5mV
20kHz to 32kHz	±2.0mV

5.5.3.4 PHASE ANGLE Mode Accuracy Checks

(a) With unit in PHASE ANGLE mode and 10V scale, apply 10V RMS to REFerence input and 10V RMS to SIGnal input from the Phase Generator.

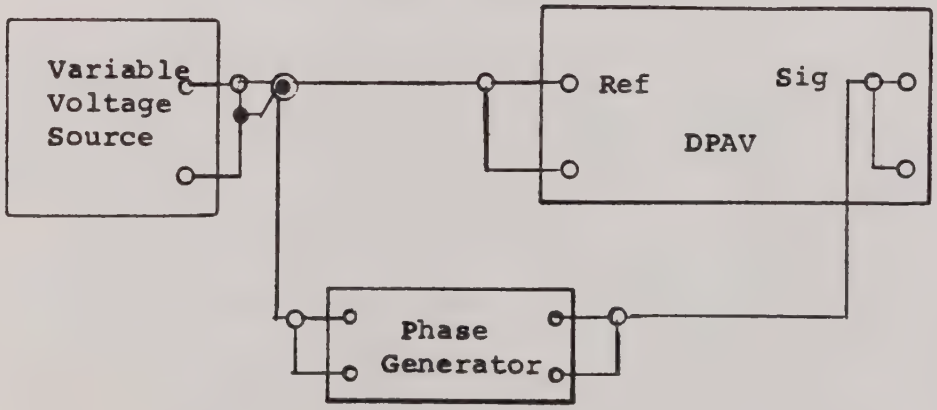


Figure 5.3. Phase Mode Set-up

(b) Phase shift the SIGnal input in 15° steps to 360° and verify accuracy as shown below. Be sure to allow for the Phase Generator accuracy.

FREQUENCY RANGE	PHASE ACCURACY
30Hz to 60Hz	0.25° + 1/2 LSB
60Hz to 5kHz	0.2° + 1/2 LSB
5kHz to 20kHz	0.25° + 1/2 LSB
20kHz to 32kHz	0.35° + 1/2 LSB

5.5.3.5 REFERENCE PHASE Mode Accuracy Checks

(a) With set-up as in 5.5.3.2(a) and Phase Generator set at +45.0°, place unit in REF PHASE mode.

(b) Turn REFerence PHASE knob for reading: 45.0°

(c) Place unit in PHASE ANGLE mode and check for reading of 0.0° to within the accuracy specified for that frequency (see 5.5.3.4(b)).

(d) Set the Phase Generator to 315.0°. With unit in REF PHASE mode, adjust REF PHASE knob for 315.0° and repeat (c).

5.5.3.6 Frequency Card Checks

Repeat 5.5.3.2 through 5.5.3.5 for each instrument's operating frequency.

5.5.3.7 Simplified Phase Checks

Due to the nature of the signal processing in the DPAV, high phase accuracy can be achieved simply by verifying the IN-PHASE and QUAD mode voltage accuracy, linearity and offsets, along with 0° phase offsets. In addition to the voltage mode, the phase digitizing accuracy can be checked by applying a coarse external phase shift or by using the REF OFFSET mode to introduce an internal phase offset.

Take IN-PHASE and QUADrature readings, calculate arc-tangent and convert to angle from a trig table. Compare the calculated angle with that displayed in the PHASE ANGLE mode. Readings should agree within 0.13° and degrade proportionally to the specifications at other frequency ranges. Readings should be checked to 10°, 30° and 40°.

TYPICAL DPAV TEST DATA SHEET

DATE _____
MODEL _____
S/N _____
FREQUENCY F_1 _____ F_3 _____
F_2 _____ F_4 _____

SIGNAL ISOLATION _____
REFERENCE ISOLATION _____
CHECKED BY _____
MISCELLANEOUS _____

5.5.2.1, 5.5.2.3 DC OFFSETS

	F_1 Read.	F_1 Spec.	F_2 Read.	F_2 Spec.	F_3 Read.	F_3 Spec.	F_4 Read	F_4 Spec
TOTAL								
IN-PHASE								
QUAD								

5.5.2.2, 5.5.2.3 GAIN TESTS

		Full Scale Read.	Spec.	Linearity	Spec.
F_1	FUND				
	IN-PHASE				
	QUAD				
F_2	FUND				
	IN-PHASE				
	QUAD				
F_3	FUND				
	IN-PHASE				
	QUAD				
F_4	FUND				
	IN-PHASE				
	QUAD				

5.5.2.4 TOTAL MODE: (NON-ISOLATED)
FREQUENCY RESPONSE:

	Reading Error	Spec.
30Hz - 60Hz		±.5%
60Hz - 30kHz		±.25%
30kHz - 100kHz		±.5%

TOTAL MODE: (ISOLATED MODE ONLY)
FREQUENCY RESPONSE

	Reading Error	Spec.
60Hz - 10kHz		±.25%
30Hz - 30kHz		±.5%
30kHz - 100kHz		±1%

5.5.3.4, 5.5.3.6 PHASE TESTS

	0°	15°	30°	45°	60°	90°	135°	180°	225°	270°	315°
F1											
F2											
F3											
F4											

5.6 ALIGNMENT AND CALIBRATION

This section contains the full alignment and calibration procedure for all adjustments in the instrument. Use the appropriate paragraphs if incorrect operation is noted or critical parts have been replaced.

If an out-of-tolerance reading is observed during performance checks (5.5) or if recalibration for accuracy is desired, refer to 5.8 Accuracy Calibration.

All functions are assumed operational. If they are not, refer to the Troubleshooting Section and to parts locator drawing for location of trims and test points. Final offset, gain and attenuator trims should be made as close to specified room temperature as possible after one-half hour warm-up with all covers on (remove top cover for final adjustments).

5.6.1 Preliminary Checks

(a) Remove top cover and check that ribbon cables are securely plugged into their headers in the right direction, and that IC's are firmly seated.

(b) Check that ground link is connected on rear panel (except for Broadband Isolation Option 05).

(c) Caution is again recommended due to the presence of line voltage and high DC voltage within the instrument.

5.6.2 Power Supply Adjustments

(a) With SIGnal and REFerence inputs shorted, monitor +5, +15 and -15V test terminals on rear of main board. Check for oscillation or excessive noise.

(b) Monitor voltages with the DC Fluke meter and adjust +15V to within ±20mV with R177 pot. Adjust -15V to within ±20mV with R175 pot. Adjust +5V to within ±50mV with R180 pot.

(c) Check that voltage on R184 is 190V ±5VDC and display is lit (assuming line voltage is 115VAC).

5.6.3 A/D Converter Adjustments

5.6.3.1 Set-up

(a) With unit in 1000mV range, IN-PHASE mode, apply an in-range REFerence input and 1000mV ±0.1% at 400Hz (or main board frequency) through a ratio box to the SIGnal input. Set ratio box to 0.0.

5.6.3.2 Clock and DC Reference Adjustments

(a) Monitor TP7 with Fluke meter and adjust R68 for a reading of -9.5VDC ±0.1V.

(b) Monitor clock pulses at TP1 with scope. Note a negative pulse train having a period of roughly 25μS and a pulse duration of about 0.75μS.

(c) Set Ratio Box to 1.0. Monitor TP5 with scope and observe a symmetrical triangular waveform with 0.0V ±0.1V positive peak and -9.5V ±0.3V negative peak. If the negative peak is not -9.5V ±0.3V, adjust pot R3 for proper value.

5.6.3.3 Voltage Mode Bias Adjustments

This section describes the adjustments for voltage mode bias to eliminate offset errors in A/D converter circuitry.

(a) With set-up in 5.6.3.1, turn power off, remove Z38, ground TP9 with jumper to TP14 and turn power on.

(b) Measure period of clock pulse train on TP1 with scope.

(c) Set R34 fully counterclockwise.

(d) Place scope probe on TP6 and adjust scope to observe a 4Hz negative-going pulse (0V to -9.5V).

(e) By varying R34 pot, adjust width of pulse to 1-1/2 times the length of the clock period measured in (b).

(f) Remove jumpers, turn power off and replace Z38. Turn power on again.

5.6.3.4 Angle Mode Bias Adjustments

(a) With set-up in 5.6.3.1, unit in PHASE ANGLE mode, with OFFSET pot, adjust in 10° with REFerence PHASE pot.

(b) Place scope probe on TP1 and externally synchronize on TP6 (DC, negative edge). The sync pulse is about 3Hz.

(c) Adjust scope for negative-going clock pulses. Increase sweep speed to observe first two clock pulses. (Disregard any pulse seen at very beginning of sweep.) The time from the beginning of sweep to the first pulse is roughly 250µS (see figure 5.4) and the time from the first to second pulse is about 500µS. Measure and record the exact time between the first and second pulses.

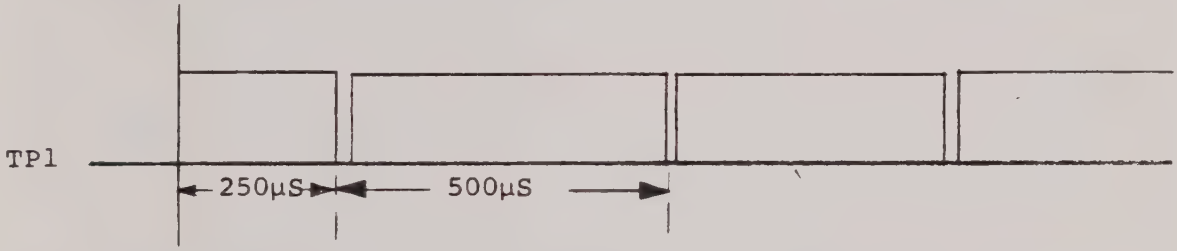


Figure 5.4 Angle Mode Clock Waveform

(d) Turn power off and remove Z36. With jumper lead, ground TP9 to ground TP14.

(e) Place scope probe on TP6 and note negative going pulses (0V to about -8V). By varying R48 pot, adjust the pulse length to equal the time between the first and second pulse recorded in step (c).

(f) Turn power off. Remove jumper and replace Z36. Turn power on.

5.6.3.5 Phase Mode Offset Adjustments:

The following steps are necessary to adjust the DC offsets on the Angle Mode segment detectors and the angle compute amplifier.

(a) With setup in paragraph 5.6.3.1, set signal ratio box to 0.0. Turn power off. Remove Z36 and Z38 on A/D Board. Turn power on and with two jumpers ground TP10 and TP11 to TP14.

(b) Monitor Z34 output at TP19 with scope and adjust R115 pot so that the voltage is just in transition between +13V and -13V.

(c) Monitor Z30 at TP18 with scope, and adjust R86 pot for a just-in transition voltage between +13V and -13V.

(d) Monitor Z31 at TP17 with scope, and adjust R95 pot so that the voltage is just in transition between +13V and -13V.

(e) With Fluke on TP8, adjust R79 for 0V ±0.1mVDC.

(f) Remove jumpers, turn power off and replace Z36 and Z38. Turn power on.

5.6.3.6 QUAD Channel Hysteresis Adjustments:

Following are the hysteresis settings for the QUAD channel absolute value amplifier made up of Z35 and Z36 stages.

(a) With set-up in 5.6.3.1, set SIGnal input ratio box to 0.0. With Fluke meter between TP12 and ground (TP14), adjust R104 pot on main board to produce -1.0mVDC at TP12 on the A/D Board.

(b) With jumper lead, ground TP21 to TP14 on A/D Board. Monitor Z35 pin 6 (cathode of CR26) with a scope, (100mV/cm) and adjust R126 until the voltage is jumping around 0V. This sets the hysteresis threshold point.

(c) Adjust R143 for 0mV ±0.2mV at TP10 (using Fluke meter).

(d) Repeat (b) and (c) until there is no interaction between R126 and R143.

(e) With -1.0mV at TP12, monitor TP10 and change ground jumper from TP21 to TP15. TP10 should now read +2mV ±0.5mV.

(f) Readjust R104 on Main Board to produce 0mV ±0.2mV at TP12 on A/D Board.

5.6.3.7 QUAD Channel Gain Adjustments

The following adjustments insure that the gain of the absolute value amplifier is the same for positive and negative inputs and also performs system gain calibration.

(a) With unit in 1000mV range, QUAD mode, apply an in-range REFerence input at 90° and 1000mV ±0.02% at 0° to SIGnal input (DC offsets were removed in previous steps). Adjust R99 pot on Main Board for -1000.0 on DPAV readout. If it goes to its stop, rotate it on its range roughly 5 turns, and adjust R68 on A/D Board for a reading of -1000.0.

(b) With same signal input, change REFerence phase to 270° and adjust R128 pot on A/D Board for +1000.0mV.

5.6.3.8 IN-PHASE Channel Hysteresis Adjustments

(a) With set-up in 5.6.3.1, set SIGnal input ratio box to 0.0. With Fluke meter between TP13 and ground (TP14) adjust R93 pot on Main Board for -1.0mVDC at TP13 on A/D Board.

(b) Ground TP20 to ground (TP14) with a jumper lead. Monitor Z37 pin 6 (cathode of CR25 with a scope (100mV/cm) and adjust R147 until the voltage is jumping around 0V. This sets the hysteresis threshold point.

(c) Adjust R168 for 0mV ±0.2mV at TP11 (with Fluke).

(d) Repeat (b) and (c) until there is no interaction between R147 and R168.

(e) With -1.0mV still at TP13, monitor TP11 and change ground jumper from TP20 to TP16. TP11 should now read +2mV ±0.5mV.

(f) Readjust R93 on Main Board for 0mV ±0.2mV at TP13 on A/D Board.

5.6.3.9 IN-PHASE Channel Gain Adjustments

(a) With unit in 1000mV range, IN-PHASE mode, apply an in-range REFerence input at 0° and 1000mV ±0.02% at 0° to SIGnal input (DC offsets were removed in previous steps). Adjust R88 pot on Main Board for -1000.0 on DPAV readout.

(b) With same signal input, change REFerence phase to 90° and adjust R153 pot on A/D Board for +1000.0.

5.6.4 Main Board Adjustments

The following adjustments complete the DPAV calibration.

5.6.4.1 Reference AGC Adjustments

Input Attenuator Adjustments

(a) Energize relay K7 by grounding Q49 collector (anode of CR63) with a clip lead. Apply about 30V p-p at 100kHz to REFerence input.

(b) Monitor TP23 and REFerence input as a Lissajous pattern on a scope. (Check phase matching of scope.) Adjust C109 for 0° phase shift. TP23 level should be about 150mV p-p.

(c) Reduce REFerence input to roughly 8V p-p and de-energize relay K7 by grounding base of Q49. Adjust C112 for 0° phase shift.

(d) Repeat this procedure until a 0° condition exists at both input levels.

(e) If Transformer Isolation Option (Option 04) is present, monitor REFerence input at E31 on Main Board.

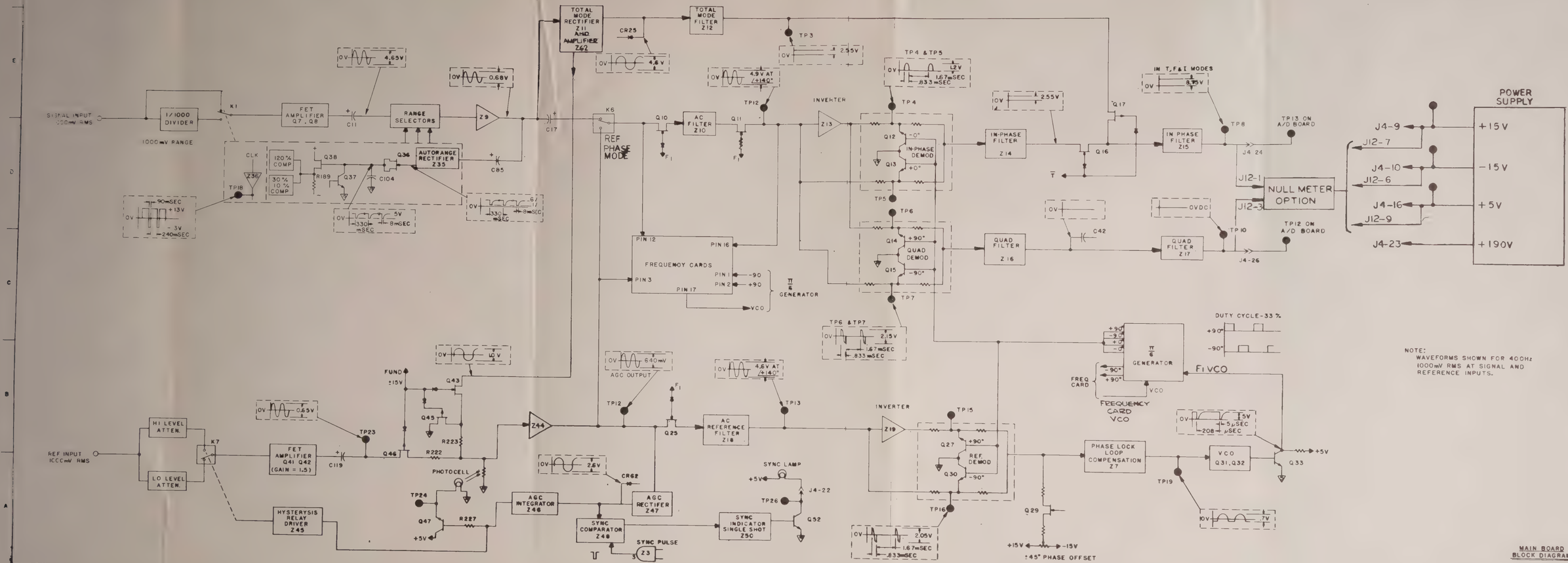
(f) If Broadband Isolation Option (Option 05) is present, remove module cover and check that DC voltage at TP1 is 0mV ±0.2mV with no REFerence input. Adjust R14 if necessary.

Monitor TP1 on module instead of TP23 on Main Board. Adjust C2 on module instead of C109 on Main Board. Adjust C11 on module instead of C112 on Main Board in these procedures.

NOTE: Instead of using Lissajous figures for phase monitoring, DC quadrature voltage at TP12 on the A/D Board may be nulled at the highest phase-sensitive frequency.

Pot Adjustments

(g) With 0V reference input and unit in IN-PHASE mode, monitor Z47 output on pin 6 with scope and adjust R275



MAIN BOARD BLOCK DIAGRAM

FIG. 5.5

for a voltage just on the positive side of the 0 line (approximately +150mV).

(h) Insert 1V RMS, 400Hz at REFerence input and monitor TP12 with AC voltmeter. Adjust level pot R232 for 230mV (.64V p-p) RMS at TP12. Check for distortion or oscillation with scope.

(i) Monitor Z46 output at pin 6 with scope. The waveform should be a full-wave rectified voltage (.7V p-p AC) riding on a DC voltage.

Increase the reference input voltage to 6.7V RMS and adjust R221 until Z46-6 voltage just starts to rise very slowly, so that it is just noticeable on scope. This sets the high threshold level for the input attenuator switch.

If Z46-6 starts to rise before the reference input voltage reaches 6.7V, adjust R221 to keep the voltage from ramping before 6.7V is reached.

Threshold Level Check

(j) After these adjustments have been made, apply 400Hz, 7V RMS at reference input and monitor Z46 pin 6 (cathode of CR60).

Lower input voltage slowly, observing scope voltage dropping toward zero. As scope voltage nears zero, lower input voltage very slowly until it snaps back into the positive region. This should occur at a reference input of 5.9V ±0.15V.

5.6.4.2 Reference Phase Lock Loop

VCO Adjust

(a) Apply a 400Hz ±0.5% in-range reference voltage and place instrument in the IN-PHASE mode, REFERENCE OFFSET "out".

NOTE: An alternate frequency measure is monitoring VCO clock output (TP25 near π/6 chop) with a frequency counter. VCO frequency is 12 times input frequency (i.e., 4800 pps).

(b) Monitor TP19 (near Z7) with scope and adjust R161 in VCO until the average value of TP19 voltage (rectified AC) is 0V ±0.5V.

(c) Adjust input frequency ±5% and observe TP19 voltage varies approximately ±8VDC.

Z7 Integrator Offset Adjust

(d) With reference input shorted, monitor the output of Z7 at TP19 with scope.

(e) Adjust R157 offset pot until TP19 voltage is near 0V and not drifting. Use a more sensitive range on scope when voltage approaches 0.

5.6.4.3 Harmonic Rejection Adjustments

Set-up

(a) Apply 10V, 400Hz REFerence input and 1V, 800Hz from another oscillator into SIGnal input on 1000mV range.

(b) With unit in QUAD mode, monitor TP10 with Fluke. Monitor SIGnal and REFerence inputs with scope. With a Lissajous figure or external scope triggering, adjust the SIGnal frequency to almost 800Hz so that the phase between the two signals is changing very slowly.

Procedure

(c) With unit in QUAD mode, monitor TP10 with Fluke and note the DC voltage changing at the "beat" frequency.

(d) Adjust pot R77 (near Z6) until "beating" at TP10 is less than 0.2mV p-p.

(e) Put unit in IN-PHASE mode, monitor TP8 with Fluke and note the DC voltage changing at the beat frequency.

(f) Adjust pot R67 (near Z6) until beating at TP10 is less than 0.2mV p-p.

Final Gain Trim

(g) Check and retrim QUAD and IN-PHASE gain by repeating §.6.3.7(a) and 5.6.3.9(a).

5.6.4.4 1000:1 Attenuator Trim

Set-up

(a) This trim should be made as close to 1.3kHz as possible for maximum sensitivity. For multi-frequency instruments, a 1.3kHz card should be used if possible.

The DC OFFSET adjustments should be made before the following:

(b) If no phase-sensitive frequency near 1.3kHz is available, this trim can be made by matching the TOTAL mode response at high and low frequencies, typically 90Hz (adjust pot R35) and 60kHz (adjust C2).

This trim must be checked at all instrument phase-sensitive frequencies, making appropriate trim changes for accuracy.

(c) If the Broadband Isolation Option is present, this trim is made through holes in the module.

Before continuing, the DC offset in the module should be adjusted. With DC Fluke meter, monitor voltage between E41 (high side of C172) and isolated ground (E40 or input low terminal). Adjust R14 on the module for a reading of 0 ±0.2mV.

(d) In transformer isolation, this trim is made in the direct mode.

(e) With unit in TOTAL mode, on 1000mV range, apply 1.0V ±0.02%, 90Hz and note readout. (Reading should be about 999.2.)

(f) Place unit in 10V range, apply 10.0V ±0.02%, 90Hz and adjust R35 on the Main Board (or R7 on the module in Broadband Isolation) for exactly ten times the reading in (a).

(g) With frequency set at 1.3kHz, or nearest phase-sensitive frequency, and appropriate Frequency Card inserted, apply an in-range REFerence voltage (not to be changed during this trim).

(h) Through ratio box, apply 1.0V ±0.02% to SIGnal input and place unit in QUAD mode. Adjust R10 on the frequency card of 0.0 ±0.2mV QUAD at TP12 on A/D Board. (DC offsets should have been removed.) Note IN-PHASE reading. If frequency being used is on the Main Board (F1) adjust R129 on Main Board for 0.0mV QUAD.

(i) Place unit in 10V range and apply 10.0 ±0.02%V RMS to SIGnal input. Adjust C2 on Main Board (or C2 on module) for QUAD reading of 0.0 ±0.2mV.

(j) Check that IN-PHASE reading is numerically identical to that in step (h) to within ±2 LSD. If it is not, readjust C2 to balance errors in the IN-PHASE and QUAD modes to within ±2 LSD.

5.6.4.5 Phase Matching

(a) Set unit to QUAD mode, with 1.0V RMS, 400Hz ±.5% in SIGnal input and 10V RMS in REFerence input, 1000mV range. (DC offsets have been trimmed out.)

(b) Monitor quadrature DC output on TP12 on A/D Board with Fluke meter and adjust phase of the reference AC filter (Z18) with R129 for 0mV ±0.5mV. This aligns the phase shift of the SIGnal and REFerence channels.

(c) Place unit in 10V range, apply 10V RMS and monitor TP10 voltage. If this voltage differs from that in (b), adjust R129 to balance phase error between 1000mV and 10V ranges. If final readings are out of spec, examine 1000:1 trim adjustment.

5.6.4.6 ±45° REFERENCE OFFSET Adjust

(a) With unit in REFERENCE PHASE mode and 1000mV range, apply an in-range REFerence voltage and 1000mV to SIGNAL input.

(b) Rotate OFFSET knob fully clockwise until display reads +47.0°. If +47.0° cannot be reached, adjust pot R149 (near Z7) on Main Board for a readout of +47.0°.

(c) Rotate knob ccw and check that it can reach at least -45.5° at its stop.

5.6.4.7 Autoranging Adjustments

In this section are the threshold adjustments and operational checkout of the autoranging circuitry for both voltage and angle modes. Step (e) is for units with voltage autoranging, step (e*) for those without.

Overrange Settings

(a) Place unit in TOTAL mode, 400Hz (if applicable), 1000mV range, and apply 0.5V RMS to SIGnal input.

(b) With scope or DC Voltmeter, monitor TP27 and adjust R204 (near A41) to approximately +9VDC.

(c) With scope or DC Voltmeter, monitor TP28 (directly behind R209) and adjust R209 (near Z42) to about +1.0VDC.

(d) Check clock at TP18. It should be +13V ±0.5V for 220mS and -13V ±0.5V for 90mS (±15%).

(e) Push the AUTORANGE button. Monitor TP27 (still approximately 9VDC as set in step (b)0. Increase the input voltage to 1.2V RMS. Adjust the overrange threshold potentiometer R204 slowly, noting voltage at TP27 lowers. Continue until the DPAV just autoranges to the 10V scale. (NOTE: TP8 can also be monitored. It will decrease by a factor of 10 after this autoranging.)

(e*) Push the PHASE ANGLE button. Monitor TP27 (still approximately 9VDC as set in step (b)). Increase the input voltage to 1.2V RMS. Adjust the overrange threshold potentiometer R204 slowly, noting voltage at TP27 lowers. Continue until TP8 just decreases by a factor of 10.

VOLTAGE Mode Underrange Setting (Not applicable for units without Autoranging)

(f) Place unit in TOTAL mode, 1000mV range, 400Hz (if applicable); apply 0.5V RMS, 400Hz to the SIGnal input.

(g) Push AUTORANGE button. Monitor TP28 (directly behind R209, about 1VDC as set in step (c)). Decrease input voltage to 0.98V RMS. Adjust the underrange threshold potentiometer R209 slowly, noting voltage at TP28 increases. Continue

until DPAV just autoranges to the 100mV scale. (NOTE: TP8 can also be monitored. It will decrease by a factor of 10 after this autoranging.)

VOLTAGE Mode Autorange Check

(h) Place unit in TOTAL mode, AUTORANGE and apply 130V RMS, 400Hz.

(i) Slowly decrease input voltage and note range change at 103V RMS. Check for AUTORANGE oscillation at threshold levels. Repeat this on each scale, noting that autoranging occurs at 10.3% ±.15% of full scale. Readjust threshold level if required.

(j) Reduce input to 0mV and note that scale stays on 10mV.

(k) Increase input voltage and note range changes at 120% ±1.5% of full scale. Note when overrange is reached, unit goes to 1000V scale and down-ranges to proper scale. This should be repeated on each scale with autoranging occurring at 120% ±.5% of full scale. Be sure there is no autoranging oscillation at threshold levels.

PHASE ANGLE Mode Under-Range Setting

(l) Signal FET Amplifier Bias Adjust. This adjustment sets the DC output of Z61 so that the DC bias voltage at Q7 does not change when K2 is energized. This prevents autorange oscillation in the PHASE ANGLE mode.

Place unit in TOTAL mode, 1000mV range and 0V in SIGnal input. Pull out Z34 chip and monitor +terminal of C11 (junction of C11 and collector of Q7) with a DC DVM. With a clip lead, ground K2 relay coil (at anode of CR3) and adjust R50 until the DC voltage does not change when K2 is energized. Change should be less than .03VDC. Replace Z34.

(m) Turn potentiometer R210 to its maximum ccw position and apply an in-range 400Hz reference voltage. Increase SIGnal input to 0.3V RMS, and switch to PHASE ANGLE mode.

(n) Adjust R210 pot slowly until threshold is reached, when the AC voltage level at the +terminal of C11 increases by a factor of 3 compared to voltage just before threshold. This

point may be monitored with either a scope or AC VTVM.

PHASE ANGLE Mode Autorange Check

(o) With 400Hz reference voltage applied, place unit in PHASE ANGLE mode and apply 130V RMS, 400Hz.

(p) Monitor +terminal of C11 (i.e., junction of C11 and collector of Q7) and slowly decrease input voltage, noting down-ranging at 30% and 10% of full scale. Be sure no autoranging oscillation appears at threshold points. Note that p-p voltage at Q7 or TP1 does not go below 30% of full scale except with less than 1mV input.

(q) Decrease input to about 2mV and note auto-ranging stops.

(r) Increase voltage and note upranging at 30% and 10% of full scale. Repeat through all ranges.

5.6.4.8 TOTAL Mode Trims

DC OFFSET Adjustments

(a) Place unit in TOTAL mode, 1000mV range and short SIGnal input. With scope, monitor Z11 rectifier output (Main Board) at pin 6 (cathode of CR46). Adjust pot R283 until waveform is jumping roughly ±100mV around 0V. Waveform should be noisy, but have no sign of oscillation.

(b) With a Fluke meter, monitor TP13 on A/D Board and adjust R116 pot (near Z12 on Main Board) for 0.0 ±0.2mVDC.

FREQUENCY Trim Procedure (Isolated & Non-isolated Units)

(c) Apply 1000mV ±0.05% from a variable frequency oscillator (30Hz to 100Hz). The oscillator should be amplitude stable with frequency (±0.02%) or monitored and adjusted with frequency. (Note 1000:1 trim has been made in 5.6.4.4.)

(d) With frequency set at 200Hz, adjust gain pot R120 (near Z12) for 1000.0 ±0.2mV.

(e) Sweep input frequency from 30Hz to 100kHz and note peaking of readout. Install select-at-test capacitors C143 and C144 (near Z11) until frequency response is flat.

(f) Isolated Mode Only: After C143 and C144 trimming adjustments, read voltages at 2kHz and 10kHz. Re-adjust R120 to balance the readings around 1000.0mV.

(g) Non-Isolated Mode: After C143 and C144 trimming adjustments, take voltage readings at 60Hz and 2kHz. Re-adjust R120 to balance the readings around 1000.0mV.

(h) Proceed with TOTAL mode frequency response in 1000mV scale and check the data gainst the specifications on page 1.4. (NOTE: If ratio boxes are used, care must be taken in their frequency response. If uncertain, monitor SIGnal input with AC Fluke meter.)

(i) Place unit in 10V range and apply 10V ±0.05% from oscillator. Sweep frequency from 30Hz to 100kHz. Check for readout response within spec. If retrim of C143 and C144 is required, the response on the 1000mV scale must be rechecked. If the 1000:1 attenuator needs adjustment, all phase-sensitive frequencies must be rechecked.

5.6.4.9 FREQUENCY CARD Trims

This section describes the calibration adjustments for each Frequency Card. Follow the steps in 5.6.4 before making these trims. Select appropriate front panel frequency button. All referenced adjustments, parts and test points are on the Frequency Cards.

Z4 Integrator Offset Adjust

(a) With REFerence input shorted, monitor the output of Z4 at TP4 with scope (5V/cm). Adjust R41 offset pot until TP4 voltage is near 0V and not drifting. Use a more sensitive range on the scope when voltage is approaching 0V.

VCO Adjust

(b) With instrument in the IN-PHASE mode, apply F_2 Hz ±0.5% in-range REFerence voltage with REFERENCE OFFSET "out".

(c) Monitor TP4 with scope and adjust R44 in VCO until average value of TP4 is 0V ±0.5V. (TP4 voltage is a "rectified" type waveform.)

DC OFFSET Adjust

(d) With unit in IN-PHASE mode and with an in-range REFerence input, short SIGNAL input in 1000mV range. With Fluke meter monitor TP12 on A/D Board (use TP14 ground on A/D Board). Adjust R18 on card for 0.0mV ±0.2mV at TP12. Monitor TP13 on A/D Board and adjust R8 on card for 0.0mV ±0.2mV at TP12.

Gain Adjust

(e) With unit in IN-PHASE mode, in 1000mV range, apply 1.0V ±0.02% through ratio box to SIGnal input and adjust card gain pot R2 for a display of 1000.0mV.

Change scale to 10V range and apply 10V ±0.02%. If reading differs from 10.000 by more than ±0.002, adjust R2 gain pot to balance the error between the 1V and 10V scale.

PHASE OFFSET Adjust

(f) With unit in QUAD mode, apply 1V at 0° to SIGnal input and monitor TP12 on A/D Board with Fluke meter. Adjust pot R10 on card for 0mV ±0.5mVDC.

Apply 10V at 0° and check TP12. If voltage is not within ±0.5mV of this reading, adjust R10 to balance it between 1V and 10V scale. NOTE: Be sure there is an insignificant phase shift through the ratio box, or measure and account for it.

±45° OFFSET Adjust

(g) With unit in REFerence PHASE mode and 1000mV range, apply 1V to SIGnal input and rotate OFFSET knob fully cw until +47.0° is displayed. If it cannot be reached, adjust R35 on card for a display of +47.0°. Rotate knob fully ccw and check that it can reach at least -45.5° at its stop.

5.6.4.10 Reference AGC Phase Adjust

(a) *Place 1000mV in signal channel and a ratio box excited by 1000mV into the reference channel. Place DPAV in QUAD mode.

*Use a ratio box with low phase shift at the frequency of measurement. An NAI RB-503C is recommended up to 10kHz, for higher frequencies, use a Dytronics RT-501.

(b) Keeping the 1000mV signal channel input constant at the highest phase sensitive frequency, measure the QUAD reading, then lower the reference input to a ratio box setting of 0.2 (200mV).

(c) Note the QUAD reading at 200mV RMS reference level.

(d) Adjust C179 for the same QUAD readout with 200mV reference level as with 1000mV (±0.1mV). If C179 cannot be adjusted, change C148 in 1pf increments.

5.6.5 Null Meter (Option 10) Adjustment

Use the DPAV in 400Hz frequency mode with signal input connected to an inverting ratio box (NAI Model 504T, or equivalent). The reference input should be held constant at 10V RMS, 400Hz. Follow each step for proper null meter operation.

(a) Place the DPAV in the IN-PHASE mode, 10V scale. Set the ratio box output to 0V RMS in-phase. Adjust R1 on the null meter board so that meter sits directly over the center line mark.

(b) Set the ratio box for 10V RMS output and adjust R3 for full deflection to the right. Reverse the input polarity by means of the ratio box and check for full deflection to the left.

(c) Check the operation of the null meter in TOTAL and FUNDamental modes as in step (b).

(d) Place the DPAV in REF PHASE mode and press reference offset adjust. Using the offset adjust on the front panel, get an offset of 45°. Press QUAD mode button and observe the null meter reads to the left approximately 50% of full scale. Press IN-PHASE mode button and note null meter reads approximately the same to the right of its null position.

(e) Check PHASE ANGLE, then REF PHASE modes. The null meter should stay on its center null position in these modes, regardless of input signal conditions.

(f) The null meter is center-weighted to be more sensitive of its null position. To check this, place DPAV

in IN-PHASE mode, 10V scale and remove the reference offset. Set the ratio box for 0mV output and observe meter reads a null. Increase the signal input voltage from the ratio box to 900mV. Note meter moves to the right to about the end of the center "black" area. Reverse input polarity by means of the ratio box and check that the meter moves to the left about the same amount. Increase the input voltage in 1V steps to 5V and check for less pronounced meter movement at each step. Reverse the input for an in-phase signal and recheck the 1V steps with the meter now moving to the right. This checks the meter sensitivity at null.

5.7 TROUBLESHOOTING

If a malfunction is not rectified by the alignment procedures in 5.6, the following should be performed.

After removing the top and bottom covers, visually inspect the unit. Some obvious causes of trouble could be:

(a) Ribbon cable plugs or IC's improperly seated.

(b) Wires broken or components loosened.

(c) Components burnt, indicating a thermal overload.

(d) Metallic particles shorting adjacent lands on PC Boards. Both sides of boards should be inspected (where convenient) and all exposed boards brush cleaned to remove dust particles.

(e) If a Beckman display tube is defective, remove the Read-out Board and replace the tube together with the associated decoder driver or drivers. This applies also to the display lamps and their drivers.

NOTE: Whenever a ribbon cable or dual-in-line IC is removed, turn power off and use proper tools to prevent damage (3M tool No. 3438, supplied, and Augat tool No. T114-1).

After completing visual inspection, perform the power supply checks in 5.7.1.

If the Power Supply checks out, the problem should be narrowed down to the A/D section or the Main Board. Apply 1000mV to the SIGnal and REFerence inputs with the unit in the 1000mV range.

Referring to the Main Board Block Diagram of Figure 5.5, check the waveforms and voltage levels, starting with TP8 and TP10. If these voltages are correct and the instrument is reading incorrectly, the problem may be in the A/D section. If the voltages are incorrect, it may be on the Main Board or a Frequency Card and can be corrected with the help of Figure 5.5 and schematics of Section VII.

5.7.1 Power Supply (Figure 7.2g)

Located on the rear of the Main Board, the power supply generates +5VDC, ±15VDC, +190VDC and two 46VDC voltages for the Broadband Isolation Modules. If a problem exists in the Power Supply, check the rear panel fuse and AC line voltage select switch S4 on the Main Board.

If a supply is out of spec (±20mV on 15V supplies, ±50mV on +5V supply) and cannot be adjusted, the ribbon cables and/or power supply jumpers (rear center of Main Board) can be removed to locate the problem. Z26 and Z27 regulators maintain 5V between pins 2 and 3. The 15V outputs are obtained by the resistor dividers feeding pin 3. Since the +15V supply feeds the +5V regulator chip Z28 (see Schematic Figure 7.2g), if one supply is out, the other will also be out.

Some representative voltages in the Power Supply:

Z26 Pin 1	+22VDC	Q35 Collector (Case)	+11
Z26 Pin 3 (Case)	+10	Z28 Pin 4	+7
Z27 Pin 1	+7	Z28 Pin 3	+5
Z27 Pin 3 (Case)	-5	Z28 Pin 10	+4.5

5.7.2 Control Switching (Figure 7.2a)

Figure 7.2a shows the switching and logic circuitry for the front panel pushbuttons and the remote control signals from the interface card.

To check out these functions, check the logic levels corresponding to the command inputs, from the front panel, or remote control. The signals are positive logic. For example, Z1 pin 10 is designated AUTO, meaning when the input command is for Autoranging, Z1 pin 10 is +5V, while Z1 pin 11 (designated $\overline{\text{AUTO}}$) is 0V.

The control signals which are not 0 to +5V are designated ±15V. These 15V signals control FET transistor switches. The frequency select signals are on the collectors of Q1, Q2, Q3 and Q4. Thus, if F2 is selected, the collector of Q2 goes to +15V and other collectors are at -15V.

In the FUNDamental mode, Q5 collector (F) is at +15V, as is Q6 collector (T). In the TOTAL mode, both collectors go to -15V.

If less than +15V or -15V is observed on these waveforms, a malfunction is in the drive circuitry or the FET switch transistors.

The 5V logic levels should be less than +0.4 for logic 0 and greater than +3.0V for TTL and +4.5V for DTL. The voltages on the SN7426 chips are 0 to +15V.

5.7.3 Reference AGC (Fig. 7.2e)

The basic operation of the AGC is described in 4.2.5. With 1000mV RMS in the REFerence input, the correct waveforms are shown in the Block Diagram of Figure 5.5.

With this input level the "LO LEVEL ATTENUATOR" is IN, producing signal levels as in Figure 5.5.

With a high level input of 100V RMS, the "HI LEVEL ATTENUATOR" should be IN, producing approximately 0.75V p-p at TP23.

In the FUNDamental mode, Q46 is turned off and Q43 is turned on, feeding a voltage from the TOTAL mode rectifier (Z11) into the AGC loop, aligning the phase of the REFerence phase-lock loop with the signal channel.

If the REFerence input level is increased to approximately 7.0V RMS, Z46 integrator (cathode of CR60) should start drifting positive. When this increasing voltage passes the 9V threshold (delayed by C133 time constant) ofZ45 hysteresis relay driver, pin 6 of Z45 goes from -13V to +13V energizing relay K7 and bringing the "HI LEVEL ATTENUATOR" in.

This should result in a stable control level in the photocell AGC loop with TP24 voltage on the lower end of its dynamic range (0 to +5V).

When troubleshooting this loop, check for:

(a) excessive DC offsets caused by faulty IC's, leaky capacitors, diodes or FET's, etc.

(b) incorrect amplifier gains

(c) distortion, etc.

If the loop is oscillating, K7 relay driver Q49 base or collector should be grounded to check the loop with at least the relay portion of the loop opened.

In Broadband Isolation, the module cover can be removed for troubleshooting.

5.7.4 NO SYNC Circuitry (Figure 7.2e)

The object of the NO SYNC circuitry is comparison of REFerence input phase with internal phase lock loop. If they are not in phase lock together, a warning signal is generated.

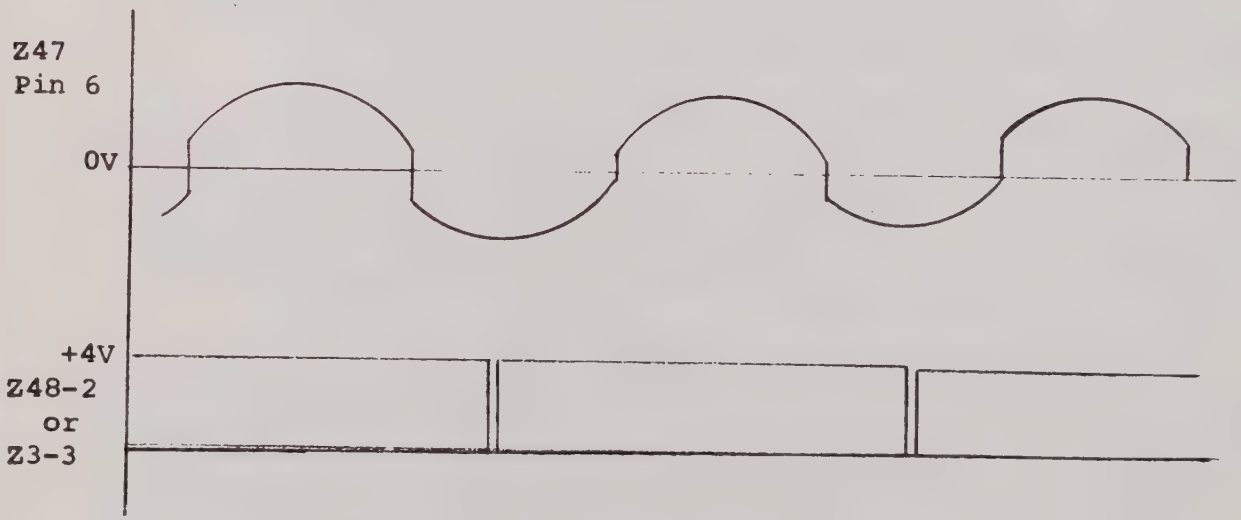


Figure 5.6. Sync Timing Diagram

Z48 is an uncompensated 709 Op-Amp used as a strobed comparator. The strobing SYNC pulse (Z48 Pin 2) is derived from the $\pi/6$ generator (figure 7.2f) and occurs during the time the signal at Z47 pin 6 is negative. The exact timing between the

two depends on any PHASE OFFSET present. If there is none, the pulse should occur near the negative peak of Z47 pin 6 signal.

With signals as in Figure 5.6, the inverting input of Z48 is always more positive than the non-inverting input. Therefore, the output remains at -13V. If the two signals go out of phase lock, the SYNC pulse will drift into the positive half cycle of Z47 signal and a positive pulse will appear at Z48 output. This pulse triggers Z50 retriggerable single shot which lights the NO SYNC bulb through Q52. (1.7 second pulse width.)

5.7.5 Reference Phase Lock Loop (Figure 7.2e)

This loop is described in 4.2.6. The demodulation waveforms on TP15 and TP16 of figure 5.5 are symmetrical around 0V, corresponding to no phase offset (Q29 off). With a phase offset, the waveforms develop DC components caused by the phase shift between the sinusoid and the chopping signals.

The DC waveform driving the VCO contains a "rectified" type AC signal. At center frequency it should have a zero DC value.

The chopper drive signals, derived from the $\pi/6$ generator, appear at Z8 pins 3 and 6. They are 0 to +15V switching signals capacitively coupled to the switching transistors Q27 and Q30. These switching signals are disabled through Q26 if another frequency is selected.

Q25 is turned off if a frequency other than Main Board F1 is selected. The VCO is also disabled.

The corresponding waveforms exist on the frequency cards. Each of these cards contains a SIGnal and REFerence filter, demodulator, compensation and VCO. The $\pi/6$ generator and PHASE OFFSET pot are shared by all frequencies.

5.7.6 $\pi/6$ Generator (Figure 7.2f)

This section of digital circuitry, located in the middle front of the Main Board, accepts a pulse train from the VCO of the selected frequency and generates the digital signals used to operate the demodulators in the REFerence phase lock loop and the IN-PHASE and QUADrature demodulator section of the SIGnal channel.

Z53 is a divide-by-12 counter providing the basic gating signals for Z55 and Z58 latches. Z52 pin 8 is the clock pulse whose leading edge is delayed (by C137 and R288) long enough to allow for the delays of the gating signals of Z53. Thus the gating signals derived from Z53 enable the clock pulse to generate the set and reset pulses for the Z55 and Z58 latches.

Figure 5.7 shows the output waveforms. If trouble is traced to this section, check that IC's are firmly seated and good contact is being made.

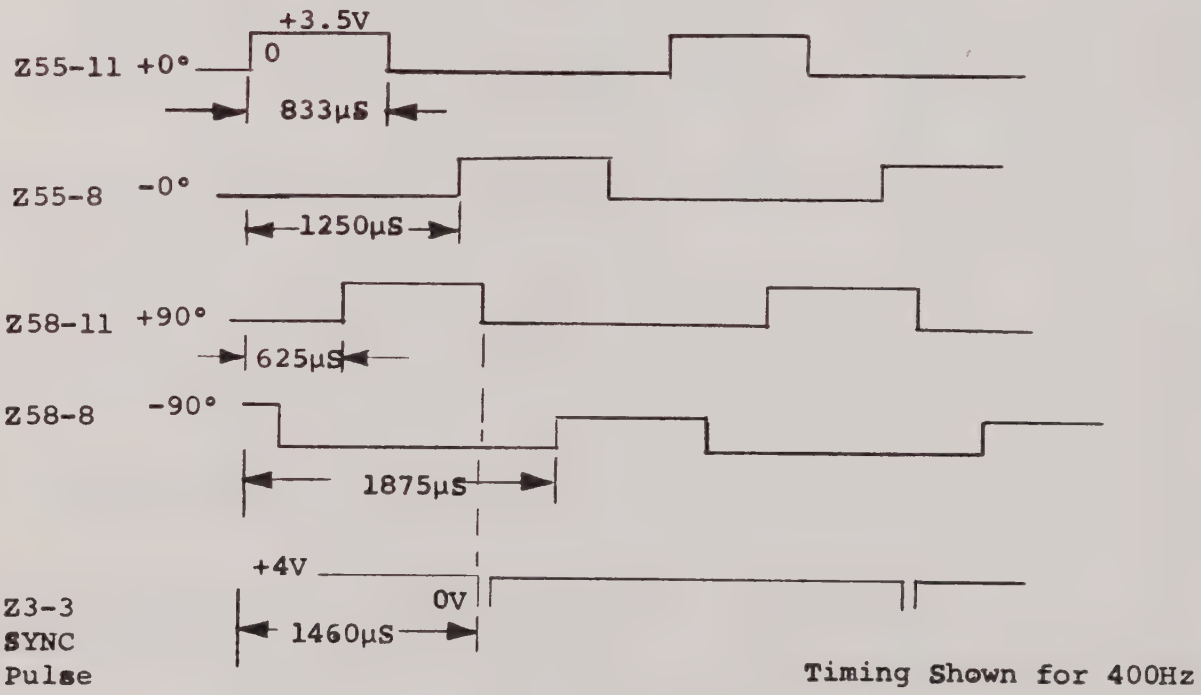


Figure 5.7 $\pi/6$ Waveforms

5.7.7 SIGnal Channel Demodulators and DC Filters (Figure 7.2c)

The key waveforms of this section are shown in figure 5.5 for a full scale signal at 0°. With a signal phase shift of 90°, the waveforms of TP4, 5 and 8 interchange with those of TP6, 7 and 10. With a signal phase shift of 180°, the polarity of the waveforms reverses.

The 0V to +15V demodulator drive signals are on Z6 pins 3, 6, 8 and 11. If any of these drive signals are missing, they should be traced to the $\pi/6$ generator (figure 7.2f).

The FUNDamental voltage is generated at TP8 in the same manner as that in the IN-PHASE voltage except there the phase-locked loop is locked into the SIGnal channel, producing a maximum, FUNDamental, voltage.

In the TOTAL mode, the rectified and filtered voltage from TP3 is fed through Q17 (Q16 is OFF) and further filtered by Z15 stage before being fed to the A/D Board.

5.7.8 SIGnal Front End (Figure 7.2b)

This section contains the SIGnal range attenuators, associated amplifiers, Main Board (400Hz) SIGnal filter and the TOTAL mode rectifier and filter. The AUTORANGING block is shown schematically in figure 7.2d.

Transformer isolated, Broadband isolated and non-isolated front ends are shown on the schematic.

In the mV ranges, the 1000:1 divider is bypassed and the SIGnal input voltage goes straight through to Q7, Q8 amplifier. With 1000mV RMS input on the 1000mV range, the output of this stage (gain roughly 1.65) is 4.65 volts peak-to-peak as shown in figure 5.5. The amplifier output (+ side of C11) is biased at about +8VDC.

On the 1000mV range, reed relay K5 is closed, providing a 100:1 attenuation. Z9 amplifier (gain = 14.6) output at TP1 should be 0.68V peak-to-peak, 0VDC and free of distortion and oscillation.

Check the 1000:1 attenuator and the decade attenuator by placing full scale inputs in all ranges and checking TP1 voltage. If more accurate readings are needed, use an AC Fluke meter or equivalent.

With certain input levels in the PHASE ANGLE mode, the gain of Q7, Q8 amplifier is raised by a factor of about 2.8. This is accomplished by the closure of reed relay K2 attaching the output of Z61 Op-Amp to the mode of resistors R41 and R55. This puts an AC short across R55 and raises the stage gain.

To check the operation of this circuit, short the SIGnal input (unit in IN-PHASE mode) in 1000mV range and momentarily energize K2 by ground CR3 anode. With scope monitor + side of C11 and check that DC bias level changes by no more than 30mVDC. Adjust pot R50 if change exceeds 30mV.

Apply a SIGnal input of approximately 30% full scale and energize K2, checking that AC voltage at C11 increases by a factor of 2.8.

If a problem exists in the Autoranging loop and the OVERRANGE light is going on, the autorange clock can be disabled by removing Z36.

The TOTAL mode rectifier waveforms are shown in figure 5.5. Z11 rectifier has a gain of 5.5, producing at its output pin (CR25 anode on figure 5.5) about 4.7V peak-to-peak with roughly a 1V discontinuity at zero volts due to the diode feedback. Z12 filter stage has a DC gain of 4.5, producing 2.55VDC at TP3 with a small amount of 800Hz ripple.

5.7.9 AUTORANGING (Figure 7.2d)

5.7.9.1 Voltage Mode

This loop operates by peak detecting the AC signal at TP1 and at the same time compares the peak to a high and low threshold. If the peak is about the high threshold, the loop upranges. If it is below the low threshold, it down-ranges. The appropriate gating is enabled from the AUTO command from Z1 pin 10.

Z35 is a high-speed rectifier whose output peak charges capacitor C104 through Q35 connected as a low leakage diode. Q38 is a high impedance buffer stage to comparators Z41 and Z42.

If an overrange condition exists, the logic output of the high threshold circuit at Z40 pin 4 will be high at sample time causing the following:

(a) Turning Q39 on lights OVLD bulb.

(b) Enables sample pulse through to Z30, pin 6. This sets the latch made up of Z29 pins 8 and 11 and drives Z29 pin 6 positive (V command) bringing the 1000:1 relay in.

(c) This same pulse at Z30 pin 6 sets the latch made up of Z30 pins 8 and 11, which also brings in the 1000:1 attenuator together with the 10 and 1000 decade attenuator relays. This action provides a faster discharge time constant for C11 for faster recovery in an overload situation. This latch (Z30 pins 8 and 11) is reset at RESET CLK PULSE time and if the unit is in an overload condition in the manual mode, this latch will toggle.

(d) The overrange enable level is inverted at Z40 pin 10 and fed to the parallel enable of the 3-bit shift register Z37 at pin 9. This presets Z37 outputs to enable the 1000 range (through Z32 pin 3) at sample clock time.

Thus, when overrange is detected, the auto-ranging loop drives the attenuators to the 1000V (actually 500V maximum) range if the input level is below 100V, the loop will down-range to the correct scale.

In an underrange condition, the voltage at TP20 goes to a logic "1" at sample time, enabling sample pulse through to Z39 pin 3 and to shift register clock input at Z37 pin 10. This initiates the shifting from the 1000 scale to the 100 scale, etc., down to the 10mV scale (in conjunction with the 1000:1 divider) if necessary.

If the unit ranges to the 10V scale and an under-range is still present, a sample pulse is gated to Z30 pin 3, driving Z29 pin 11 latch to the mV state. This takes the 1000:1 attenuator out, while the shift register goes to 1000, placing the unit in the 1000mV scale.

For inputs below 1mV, the ranging is frozen in the 10mV scale as follows:

Z39 pin 10 is high ("10" range from shift register) and Z39 pin 9 is high ($\overline{V}$), producing a low at Z39 pin 8. This low feeds to Z40 pin 9 disabling the underrange command, which disables the shift register clock at Z39 pin 3, keeping the range at 10mV.

5.7.9.2 Angle Mode

In the PHASE ANGLE mode (θ), the autoranging works the same, except for an intermediate gain change. On any range, the gain of the FET amplifier (Q7, Q8) is increased by a factor of about 3 whenever the SIGnal input goes below 30% full scale.

When Q40 turns off, the low threshold (Z42 comparator) is increased to 30% of full scale, producing an under-range logic signal at TP20 when the input goes below 30% full scale.

The devices related to this mode include Q20, Q40, Z34, Z43 and parts of Z31 and Z40. The X3 gain increase is activated by Z34 pin 6, driving the coil of K3, meaning a logic low at Z34 pin 6 corresponds to Z3 gain increase.

If an under-range condition is sensed (TP20 high) and X3 gain is not in, Z34 pin 8 will be low. This low inverts to a logic "1" at Z43 pin 13. Z43 pin 12 is high from TP20, producing a low at Z43 pin 11 and also Z39 pin 2. This disables a clock pulse from reaching the scale, changing circuitry. However, Z34-11 will be enabled and the next clock at Z34 pin 9 will bring Z34 pin 6 low and pull in the X3 relay K2.

If an under-range condition remains with the X3 relay in, Z39 pin 2 will no longer be disabled (through Z43 pin 11) so that the next pulse will change scale. At the same time, Z34 pin 8 being high, as in the under-range signal (TP20), Z31 pins 12 and 13 are high, enabling Z34 pin 4 so that the X3 relay will be taken out at sample time.

An over-range in the θ mode will cause the X3 relay to be taken out and the least sensitive scale switched in. The over-range signal at Z40 pin 4 produces a logic "0" at Z43 pin 10. This enables Z34 pin 4, taking the K3 relay out at sample time.

Effectively, the range cycling during autoranging in the PHASE ANGLE mode is: 1000V, 300V, 100V, 30V, etc.

TABLE 5.1. AUTORANGE TROUBLESHOOTING CHART

This chart lists some possible malfunctions and their probable, but not necessarily only, cause. Before proceeding, check the range attenuators in the manual mode (with appropriate inputs) and the clock at TP18.

Problem	Possible Causes
1. Ranges oscillate between scales in voltage mode	a) Z41 and/or Z42 threshold level detector misaligned.
	b) excessive DC offset at Z9 pin 6
	c) Q37 not discharging C104 to zero voltage at reset pulse time.
	d) faulty operation of Z37 shift register.
	e) check power supplies, volt. & ripple
2. Ranges oscillate in PHASE ANGLE mode	a) check above items.
	b) DC bias at Q7 collector changes when K2 is energized (adjust R50)
	c) FET amplifier (Q7, Q8) does not increase in gain by a factor of 2.8 when K2 is energized. (Check Z61 and FET amplifier.)
	d) faulty operation of Z34 flip-flop
3. Fails to range to 500V scale in overload	a) check items in problem 1.
	b) Sample pulse at Z38 pin 2 not getting to Z37 shift register or Z29 latch (check appropriate gating chips).
	c) Z29 latch or gate failure
4. Fails to down-range in underrange condition	a) Check items in problem 1.
	b) sample pulse at Z38 pin 2 not getting to Z37 shift register or Z29 latch (check gating chips).
	c) Z29 latch or gate failure
	d) Z34 failure (in θ mode) or in gating to Z34

The following timing diagrams will assist the check-out of the digital circuitry of the autoranging loop.

With SIGnal input shorted and unit in IN-PHASE mode and AUTORANGE, remove Z42 Op-Amp and jumper TP20 to TP21. These test points are at logic "1" since an over-range condition does not exist and this gives the under-range command to the digital circuitry, causing the unit to cycle down-range. When the 10mV range is reached, Z39 pin 8 goes low, feeding the low back to TP20 and TP21, simulating an over-range, bringing the unit to the 1000V range and starting the cycle over again (see figure 5.8).

In the PHASE ANGLE mode, the X3 gain relay K2 waveform at Z34 pin 8 is shown in figure 5.9.

5.7.10 A/D Converter

The A/D and Read-out Board troubleshooting procedure is in three sections for isolating the faulty circuits.

5.7.10.1 Preliminary Set-up

(1) Place 1000mV RMS in both SIGnal and REFerence channels.

(2) Place voltmeter on 1V scale, mode in TOTAL.

5.7.10.2 Preliminary Checks

(1) The A/D Board clock, detectable at TP1 on A/D board must be operational for any A/D conversion. Trouble-shooting should not be attempted until clock is restored.

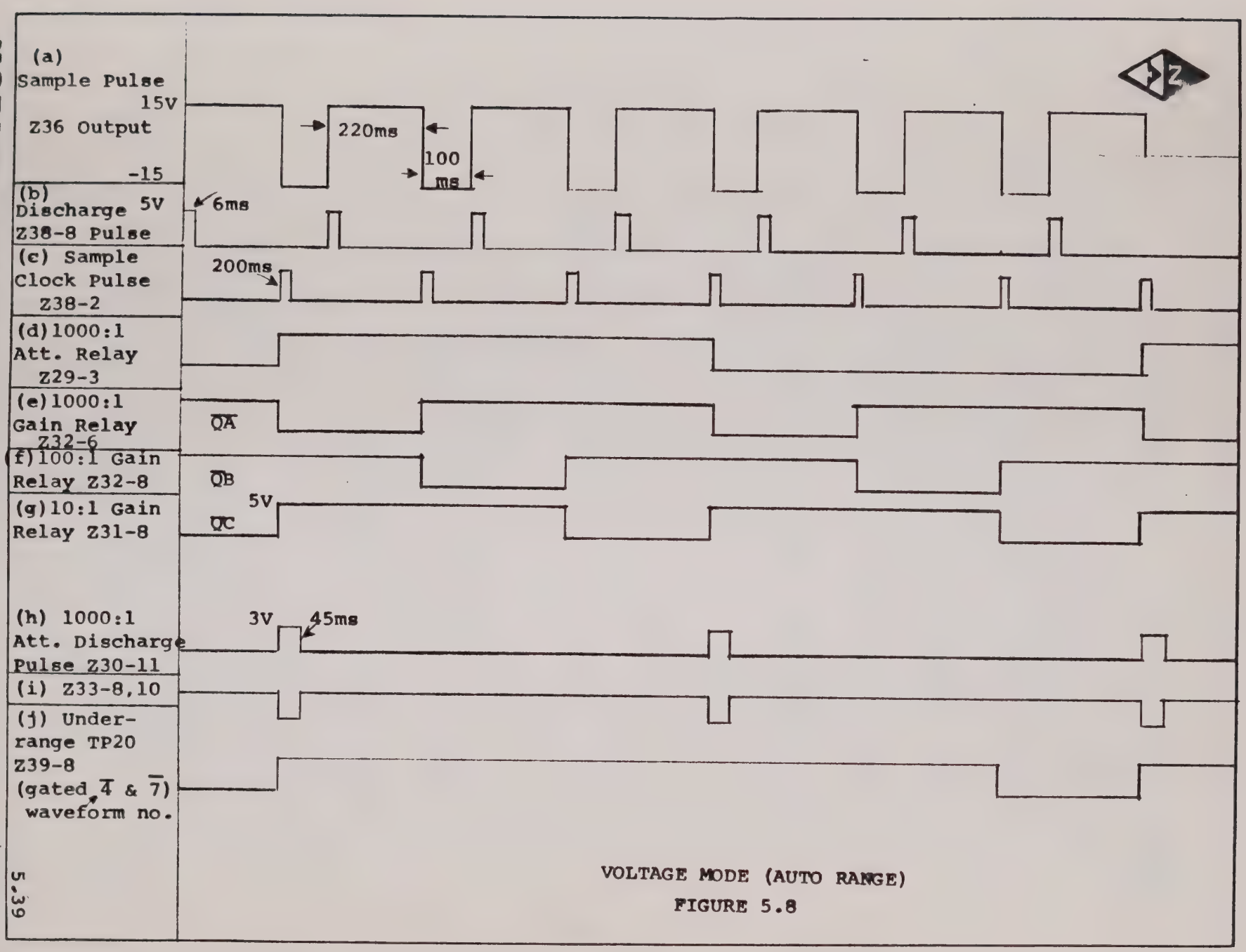
(2) A/D Board reference voltage at TP7 must be present for an accurate A/D conversion. Restore A/D reference voltage before proceeding. Vref = -9.500V ±3%.

5.7.10.3 SECTION #1

(1) Monitor A/D Board TP13 with DC voltmeter.

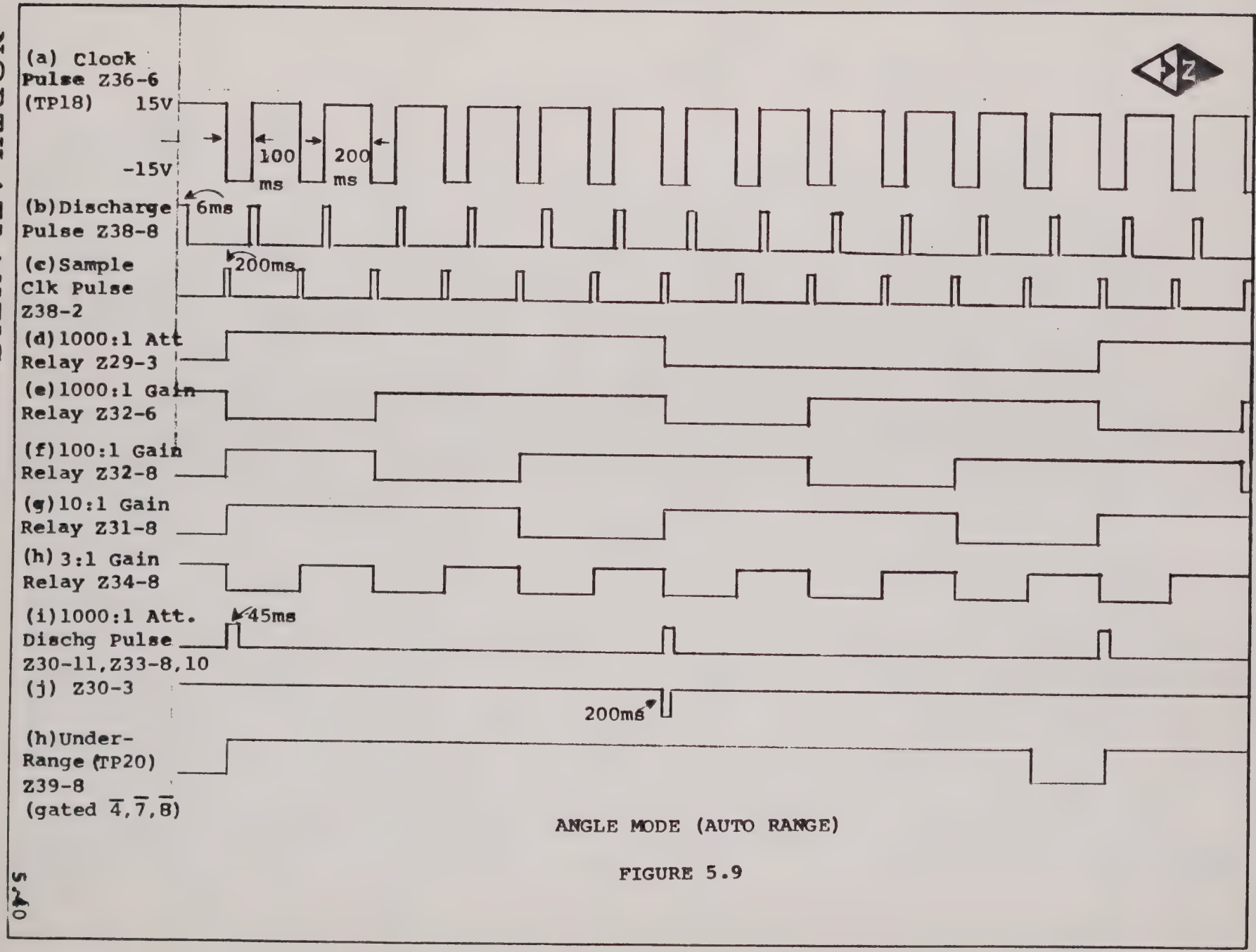
(a) Voltage should be 1.0VDC. If so, continue ....

(b) If TP13 voltage is not 8.75VDC ±5%, refer to Main Board Troubleshooting Procedure.



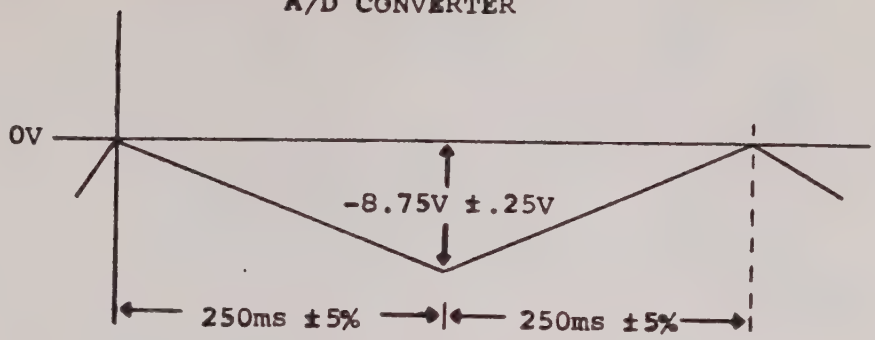
VOLTAGE MODE (AUTO RANGE)

FIGURE 5.8

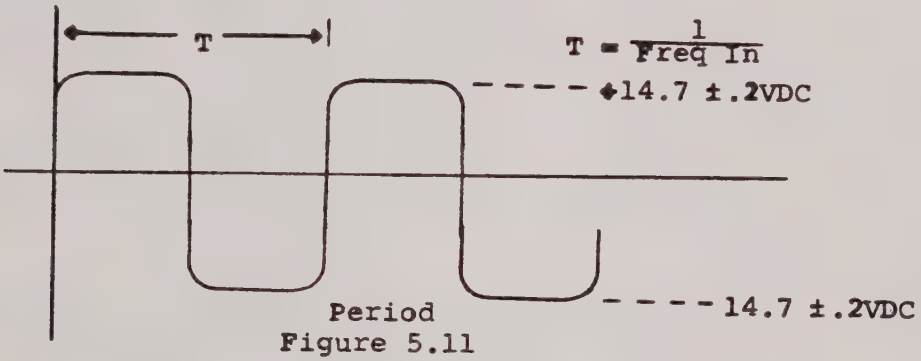


ANGLE MODE (AUTO RANGE)

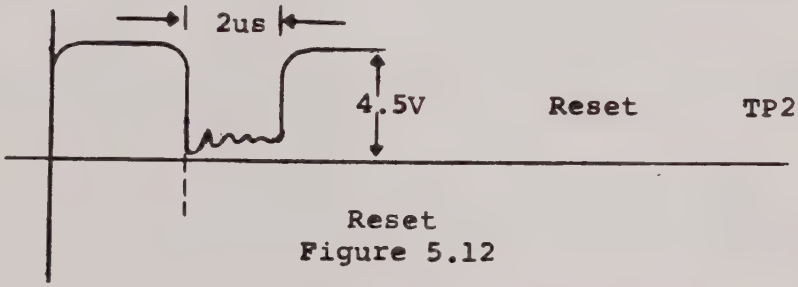
FIGURE 5.9



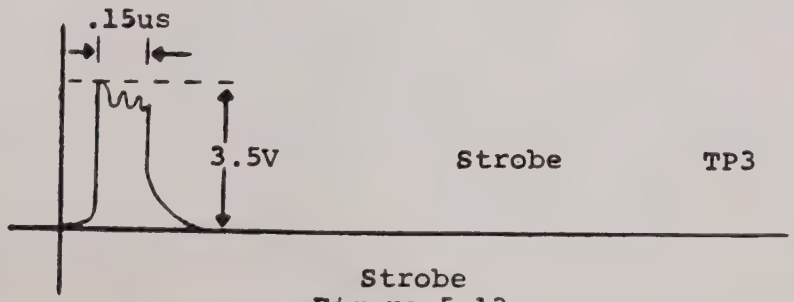
Dual Slope Ramp
Figure 5.10



Period
Figure 5.11



Reset
Figure 5.12



Strobe
Figure 5.13

(2) Monitor A/D Board TP5 with scope.

(3) Dual slope ramping at this point should be as shown in figure 5.10.

(a) If so, proceed to Section 3.
(b) If not, continue ....

(4) Remove DIP's Z22 and Z14 from A/D Board. (Disregard digital read-out)

(5) Prepare a ground lead with probe tip.

(6) Monitor A/D Board TP5 with oscilloscope.

(7) Check for digital spillover pulses on A/D Board connector J1-10.

(a) If no pulses, proceed to Section 2.

(8) Touch and hold grounding probe to Z13 pin 2 on A/D Board.

(9) Monitor TP23 on A/D Board with oscilloscope.

(a) TP23 voltage should correspond to a DTL logic "zero": $0V < VTP23 < +5mVDC$.
(b) TP23 voltage must jump to a DTL logic "one" upon removal of grounding lead from Z13 pin 2. If so, continue ....
(c) If (a) or (b) do not meet requirements, the most probable cause of failure are Z13, 19, 22.

(10) Monitor A/D Board test point 5 with oscilloscope.

(11) Touch and hold grounding probe to Z13 pin 1 on A/D Board.
(a) Oscilloscope trace should sink slowly to approximately -15 volts.
(b) Oscilloscope trace should rise rapidly to the axis when ground probe is removed from Z13 pin 1.
(c) If TP5 responds correctly, proceed to Section 2.
(d) If not, continue .....

(12) Monitor A/D Board TP6 with oscilloscope.

(13) Touch and hold grounding probe to Z13 pin 1 on A/D Board.

(a) Trace should dip to -9.5VDC.

(b) Trace should jump back up to +1.0VDC when grounding probe is removed.

(c) If TP6 voltage does not respond correctly and does not change, the most probable causes of failure are Q10 through Q16 and their associated drive circuits.

(d) If TP6 voltages respond correctly, the possible failure group consists of Z24, Z25 and associated components.

5.7.10.4 SECTION 2

(1) Replace Z22 and Z14 on A/D Board removed in Section 1.

(2) Remove Z25 on A/D Board.

(3) Prepare and connect a test lead to TP5 on A/D Board and the signal input terminal on the front panel of DPAV. Do not remove signal lead until instructed.

(4) Monitor A/D TP4 with oscilloscope.

(a) Waveform must appear as a rounded corner square wave of a period equal to that of the sinusoidal input. See figure 5.11. If waveform is correct, continue ....

(b) If no waveform appears or some other wave-shape occurs, the failure group consists of Z23 and associated parts.

(5) Monitor A/D Board TP3 with oscilloscope. Be careful in observing the pulse waveform at this point because of its short duration of 250-400nS. (See Figure 5.13.)

(a) If waveform appears, continue .....

(b) If not, the probable cause of failure is Z21 and associated components.

(6) Monitor A/D Board TP2 with oscilloscope. Be careful in observing the pulse waveform due to its short duration of 300-400nS. (See Figure 5.12.)

(a) If pulses are present, proceed to Section 3 after replacing Z25 on A/D Board and removing test lead from TP5.

(b) If not, the failure group consists of Z20 and associated components.

5.7.10.5 SECTION 3 - Readout Board Overall Check

(1) Remove Z21 and Z15 from A/D Board.

(2) Connect variable frequency square-wave generator to A/D TP1 and ground.

NOTE: Pulse generator output should be no greater than 5V peak before connection to TP1.

(3) The external square-wave generator connected to TP1 will cause the digital Readout Board to count in a decimal fashion the number of input square waves. Vary the frequency of the square-wave generator from 400mS/pulse to 400μS/pulse in descending powers of ten in order to cause each significant digit to count in decimals from 1, 2, 3....9 and back to 0 (except over-range digit, which should remain lit).

(a) If each digit operates correctly, continue ....

(b) If not, troubleshoot as explained in table.

TABLE 5.2

	Over-Range Digit	4th SD	3rd SD	2nd SD	1st SD
Probable Failure Group	Z11,Z12,Q1	Z1,Z5,Z9	Z2,Z6,Z10	Z3,Z7,Z11	Z4,Z8,Z12

(4) Using the variable frequency square-wave generator, send an arbitrary number of pulses into TP1 to cause each significant digit to read any number other than zero. Disconnect generator.

(5) Prepare and connect for one second a grounding probe to the A/D Board connector J1, Pin 2.

(a) All digits but the over-range must toggle to zero.

(b) If all digits respond, continue....

(c) If not, troubleshoot its respective operators.

(6) Attach a ground to A/D Board TP3 when all digits except the over-range read zero. Remove ground only when instructed.

(7) Reconnect square-wave generator to A/D Board TP1.

(8) Vary the frequency of the input pulses and observe the readout board.

(a) All digits must remain zero. If so, continue .....

(b) If a digit fails to remain zero, troubleshoot its respective probable failure group as shown in table.

(9) Disconnect ground from A/D Board TP3 temporarily.

(10) Set the square-wave generator to a frequency of 2kHz.

(11) The Readout Board is now counting at a rate of 2kHz. Temporarily touch ground lead to TP3 and observe Readout Board.

(a) Readout Board digits must be frozen, and no digit must change while ground lead is still attached.

(b) If a digit fails to freeze, troubleshoot its respective probable failure group as shown in table.

(c) If all digits freeze correctly, the problem is of a subtle nature and will require independent troubleshooting.

5.8 ACCURACY CALIBRATION

This section contains the trimming procedures for an out of tolerance condition in the Performance Checks of 5.5.

For an operation problem or adjustments not covered in this section, refer to the full Alignment and Calibration section of 5.6 and the Troubleshooting section of 5.7. The trims in this section are also a part of 5.6.

The following is performed with 10V RMS in the REFerence input from a Phase Generator and the SIGnal input derived from a precision ratio box.

The accuracy trims should be made after the instrument has warmed-up for 30 minutes minimum at room temperature. Remove top cover and make trims as rapidly as possible to preserve thermal equilibrium.

5.8.1 Main Board Frequency (F1) DC Offset Adjustments

5.8.1.1 With REFerence frequency set to F1 Hz ±1%, short the SIGnal input with unit in 1000mV scale and IN-PHASE mode.

5.8.1.2 With DC Fluke meter, monitor TP13 on A/D Board (top front of unit) using the ground test point on A/D Board. Adjust trimpot R93 on Main Board for a reading of 0.0 ±0.2mVDC on the Fluke.

5.8.1.3 Place unit in QUADrature mode and monitor TP12 on A/D Board with Fluke meter. Adjust trimpot R104 on Main Board for a reading of 0.0 ±0.2mVDC on the Fluke.

NOTE: If, after the trims of 5.8.1.2 and/or 5.8.1.3, the readout is ±0.3 or greater, the hysteresis adjustments of 5.6.3.6 and/or 5.6.3.8 should be made.

5.8.2 Frequency Card DC Offset Adjustments

5.8.2.1 With REFerence frequency set to F2 Hz ±1%, short SIGnal input with unit in 1000mV scale and IN-PHASE mode.

5.8.2.2 With DC Fluke meter, monitor TP13 on A/D Board. Adjust R8 trimpot on appropriate frequency card for a reading of 0.0 ±0.2mVDC on the Fluke.

5.8.2.3 Place unit in QUADrature mode and monitor TP12 on A/D Board with Fluke. Adjust R18 trimpot on appropriate frequency card for a reading of 0.0 ±0.2mVDC on the Fluke.

5.8.2.4 Repeat these procedures for remaining phase-sensitive frequencies in the instrument.

5.8.3 TOTAL Mode DC Offsets

5.8.3.1 Place unit in TOTAL mode, 1000mV range and short SIGnal input. With a scope, monitor Z11 rectifier output (Main Board) at pin 6 (cathode of CR46). Adjust pot R283 until waveform is jumping roughly ±100mV around 0V. Waveform should be noisy, but have no sign of oscillation.

5.8.3.2 With a Fluke meter, monitor TP13 on A/D Board and adjust R116 pot (near Z12 on Main Board) for 0.0 ±0.2mVDC.

NOTE: For non-isolated units, take care to avoid ground loops. It may be necessary to remove the REFerence input when making these adjustments.

5.8.4 IN-PHASE and QUAD Gain and Phase Adjustments

5.8.4.1 With frequency at F1 Hz, apply 1.0V ±.02% to SIGnal input, IN-PHASE mode on 1000mV scale. Select appropriate frequency button.

5.8.4.2 Adjust Main Board gain trimpot R88 (near Z14) for a readout of 1000.0 ±0.2mV. This adjustment can also be made by R161 on A/D Board.

5.8.4.3 Change REFerence input phase 180° and check for readout of 1000.0 ±0.2mV. If it is not, adjust R161 on A/D Board for 1000.0 ±0.2mV, then place in 0° REFerence and adjust R153 on A/D Board for 1000.0 ±0.2mV.

5.8.4.4 Place unit in QUAD mode and apply +90° REFerence input with same SIGnal input. Adjust R99 trimpot on Main Board (or R132 on A/D Board) for a readout of -1000.0 ±0.2mV.

5.8.4.5 Change REFerence phase to +270° and adjust R128 pot on A/D Board for +1000.0 ±0.2mV.

5.8.4.6 With unit in QUAD mode and 1000mV scale, apply 1.0V RMS at 0° to SIGnal input. With Fluke, monitor TP12 on A/D Board and adjust Main Board trimpot R129 (near Z18) for 0.0 ±0.5mVDC.

5.8.4.7 The IN-PHASE gain and 0° QUAD levels should be checked on the 10V scale with 10V input to check the 1000:1 divider. If the 10V readings exceed 30% of the gain and phase specs at the frequency of interest, the 1000:1 divider trim of 5.7.4.4 should be made.

5.8.5 Total Mode Gain Trim

5.8.5.1 With unit in TOTAL mode, 1000mV range, apply 1.0V ±.02% at 400Hz to SIGnal input.

5.8.5.2 Adjust Main Board trimpot R120 for a reading of 1001.0mV ±0.2mV. This high setting allows for a gain dip at higher frequencies.

5.8.6 Frequency Card Gain and Phase Trims

5.8.6.1 With unit in IN-PHASE mode, 1000mV range, apply 1.0V ±0.02% at F2 Hz ±1% with appropriate frequency selected on front panel.

5.8.6.2 Adjust R2 pot on appropriate frequency card for a readout of 1000.0 ±0.2mV.

5.8.6.3 Place unit in QUAD mode and adjust R10 trimpot on frequency card for a readout of 0.0 ±0.3mV.

5.8.6.4 Check 10V scale as in 5.6.4.6.

5.8.6.5 Repeat these procedures for remaining instrument frequencies.

REPLACEMENT PARTS LIST

NOTE: Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components functionally interchangeable for any of the parts shown in this parts list.

MAIN BOARD (PL-500869)

DESIGNATION	PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C8,C10,C166	802422	3	Capacitor, Mica, 10pf 500V, ±10%	72136	DM15D100JP 500WV4CR
C11,C17	801093	2	Capacitor, Tantalum, 22μf 20V	56289	150D226X00 20R2
C[illegible],C101 C120	806884	2	Capacitor, Ceramic, 5pf 1000V ±.25pf	72982	831000COGO 509C
C[illegible],C39,C43 C48,C53,C78 C129	802338	6	Capacitor, Mica, 39pf 500V ±10%	84171	DM-15390K
C14,C16,C89 C90,C92,C93 C95,C149, C162	806086	9	Capacitor, Ceramic,0.1μf 25V +80-20%	72982	5815000Y5-00104Z
C[illegible],C107 C124,C165	801686	3	Capacitor, Mica, 75pf 500V ±5%	72136	DM15E750J
C21,C22,C26 C27,C40,C41 C44,C45,C57 C58,C66,C68 C70,C73,C122 C123,C130 C131,C150 C151,C181, C182	803406	22	Capacitor, Ceramic,0.01μf 25V +80-20%	71590	UK25-103
C24,C87,C142	802420	3	Cap., Mica, 2pf, 500V ±20%	72136	DM-15020D
C25,C28,C31 C33,C37,C56 C82,C86,C99 C126,C132, C134,C137	806883	13	Capacitor, Ceramic, 150pf 1000V ±10%	72982	831000X5-F0151K
C29,C30,C32 C34,C35,C36 C74,C75,C81 C84,C133 C161,C170	806890	13	Capacitor, Electrolytic 10μf, 25V -0+100%	24138	PCD10PB25

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C38,C42,C59 C63	807569	4	Capacitor, Polyester Film 1.0uf, 250V, ±10%	74861	1LMZP100
C46,C52	807554	2	Capacitor, Polyester Film 1.5uf, 250V, ±10%	74861	2.5LMZP150
C47,C51	806694	2	Capacitor, Polyester Film .15uf, 80V, ±5%	06001	AE22R154J
C71	805602	1	Capacitor, Ceramic, 200pf 1000V, ±10%	72982	831000X5FO-201K
C72	805620	1	Capacitor, Ceramic 5000pf, 1000V, ±10%	72982	811000X5-RO502K
C85	807392	1	Capacitor, Tantalum 4.7uf, 20V, ±20%	56289	475X0020EB
C88,C91	806904	2	Capacitor, Alum. Electrolytic, 2700uf, 40V	37942	CGS272U040R2C
C94	806905	1	Capacitor, Alum. Electrolytic, 6800uf, 25V	37942	CGS6820025R2-L3PH
C96	806902	1	Capacitor, Ceramic 6800pf, 1000V, ±20%	72982	CK62AW682M
C97	807169	1	Capacitor, Alum. Electrolytic, 1.0uf, 50V, +150-0%	24138	PCD1-PA50
C98	807204	1	Capacitor, Alum. Electrolytic, 40uf, 350V	37942	TCG400T350G-213P
C104	806897	1	Capacitor, Polycarbonate .022uf, 50V, ±10%	74861	W625B1A223K
C105,C127	807324	2	Capacitor, Polyester Film .33uf, 200V, ±10%	74861	2LMZP33

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C113,C117,C125 C156 thru C159 C167,C173,C174	806891	10	Capacitor, Aluminum Electrolytic 100uf, 25V, -0% +100%	24138	PCD100PG25
C119	807346	1	Capacitor, Alum, Elect. 1000uf, 16V, -0% +100%	24138	PCD1000-PN16
C121	801687	1	Capacitor, Mica 91pf, 500V, ±5%	72136	DM15-910J
C128	802421	1	Cap., Mica 5pf,500V,±10%	72136	DM15-050K
C ,C171	801685	1	Capacitor, Mica 50pf, 500V, ±5%	72136	DM15-500J
C135	805357	1	Capacitor, Ceramic 1500pf, 100V, ±10%	72982	8133000W-5R0152K
C136	800596	1	Capacitor, Tantalum 2.2uf, 20V, ±20%	56289	150D225X-0020A2
C143		1	Capacitor, Mica, nominal 390pf, Select at Test		
C144		1	Capacitor, Mica Select at Test		
C145	801786	1	Capacitor, Mica 390pf, 500V, ±5%	72136	DM15F391J-P500WV4CR
C146	807028	1	Capacitor, Ceramic .022uf, 50V	72982	81210506-51223M
C148	802619	1	Capacitor, Mica 1pf, 500V, ±.5pf	72136	DM15-010K
C160,C163,C164	807194	3	Capacitor, Aluminum 20uf, 16V	24138	PCD20PB16
C169	800594	1	Capacitor, Tantalum 4.7uf, 10V, ±20%	56289	150D475X-001A2
C172	802422	1	Capacitor, Ceramic 10pf, 500V, ±10%	72136	DM15-100
C179	806970	1	Capacitor, Variable 0.25-1.5pf	74970	273-0001-002
C180	800510	1	Capacitor, Tantalum 10uf, 15V, ±20%	56289	150D106X-0015B2
C183	807603	1	Capacitor, Variable 7-40pf	72982	518000-G-7-40pf

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT;	MFR PART NO.
CR4,CR5,CR6 CR9,CR12, CR14,CR16 CR19,CR21 CR22,CR27 CR28,CR29 CR31,CR33 CR35,CR51 thru CR60 CR64 thru CR67,CR70, CR72,CR74 CR75	802924	34	Diode, 1N3069	07263	1N3069
CR13,CR15 CR17,CR20 CR32,CR34	807217	6	Diode, Zener, 3.6V	04713	1N5229
CR18	806951	1	Diode, Zener, 5.1V	04713	1N5231
CR25,CR46 CR49,CR50 CR61,CR62 CR73	806330	7	Diode	NAI	
CR45	807326	1	Diode, Zener, 6.2V	04713	1N821A
CR76	807650	1	Diode, Zener 20.V	12969	UZ5820
F1	803877		Fuse, .5A (115V)	75915	313.500
	807117		Fuse, .25A (220V)	75915	313.250
J4	807107	1	Header	76381	3429-2002
J7,J8	807212	2	Connector	16512	HC-200147
K3,K4,K5	806971	3	Relay	MFR 3	530-4-1A
K6	806959	1	Relay	MFR 2	530-4-1C
L1 thru L4 L6 thru L8	804836	7	Choke, 33uh, 187mA	76493	9230-56
Q5,Q6,Q31	805059	3	Transistor, 2N2906	04713	2N2906
Q7,Q42	803661	2	Transistor, 2N3906	04713	2N3906
Q8,Q38,Q41	806213	3	Transistor, 2N5246	01295	2N5246

Rev A - 11/18/74
Rev B - 12/9/74
Rev.C - 1/31/75
Rev.D - 4/7/75

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
Q9,Q20,Q26 Q33,Q37,Q39 Q47,Q49,Q51 Q52	806949	10	Transistor, BC338	73445	BC-338
Q10,Q11	804583	2	Transistor, TIS73	01295	TIS73
Q12,Q13,Q14 Q15,Q27,Q30	807479	6	Transistor, 2N6002	03508	2N6002
Q16,Q25	805808	2	Transistor, TIS75	01295	TIS75
Q17,Q45,Q46	804360	3	Transistor, 2N4360	07263	2N4360
Q32	804318	1	Transistor, 2N4851	04713	2N4851
Q35	806844	1	Transistor, 2N3055	02735	2N3055
Q36,Q43,Q53	803662	3	Transistor, 2N3819	01295	2N3819
Q56	800872	1	Transistor, 2N1381	01295	2N1381
R1 thru R4 R8 thru R13 R25,R26,R28 R29,R122,R173 R228	801985	17	Resistor, Composition 51KΩ, 1/4W, ±5%	01121	CB5135
R23,R24,R136 thru R138 R141,R154 R R194 R245,R268 R113	801006	11	Resistor, Composition 10KΩ, 1/4W, ±5%	01121	CB1035
R27,R30 R191,R193 R278,R284	802757	6	Resistor, Composition 150KΩ, 1/4W, ±5%	01121	CB1545
R37,R45,R163 R215	802188	4	Resistor, Composition 4.3KΩ, 1/4W, ±5%	01121	CB4325
R39,R166 R214	803673	3	Resistor, Composition 330Ω, 1/4W, ±5%	01121	CB3315
R41	807174	1	Resistor, Metal Film 510Ω, 0.3W, ±0.1%	18612	V53-1
R42	806926	1	Resistor, Metal Film 2KΩ, 0.3W, ±0.1%	18612	V53-1

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R43,R219	801004	2	Resistor, Composition, 1kΩ 1/4W ±5%	01121	CB1025
R46	806921	1	Resistor, Metal Film, 9kΩ 0.3W ±0.02%	18612	V53-1
R47	806922	1	Resistor, Metal Film, 900kΩ 0.3W ±0.02%	18612	V53-1
R48	806924	1	Resistor, Metal Film, 100Ω 0.3W ±0.02%	18612	V53-1
R51	807175	1	Resistor, Metal Film, 735Ω 0.3W ±0.1%	18612	V53-1
R52	807176	1	Resistor, Metal Film, 10kΩ 0.3W ±0.1%	18612	V53-1
R53,R56,R71 R75,R80,R83 R98,R109,164 R143,R144, R217,R292	801094	13	Resistor, Composition, 2kΩ 1/4W ±5%	01121	CB2025
R ,R112, R227,R251 R255,R257	802080	5	Resistor, Composition, 8.2kΩ 1/4W ±5%	01121	CB8225
R55	807173	1	Resistor, Metal Film, 2.4kΩ 0.3W ±0.1%	18612	V53-1
R65,R68, R69,R73,R74 R78,R79,R85 R86,R170	806919	10	Resistor, Metal Film, 20kΩ 0.3W ±0.1%	18612	V53-1
R66,R90 R101,R183, R295,R301	801721	6	Resistor, Composition, 12kΩ 1/4W ±5%	01121	CB1235

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R67,R77	806909	2	Potentiometer, miniature, 500Ω	32997	3389P-1-501
R70,R76,R81 R87,R147 R151,R223 R230,R237 R244,R270	801988	11	Resistor, Composition, 15kΩ,, 1/4W ±5%	01121	CB1535
R72,R84	807184	2	Resistor, Metal Film, 240Ω, 1/4W ±2%	16299	C4
R82	802258	1	Resistor, Composition, 560Ω 1/4W ±5%	01121	CB5615
R88,R99,R120	807195	3	Potentiometer, film, 2kΩ	32997	3299W-1-202
R89,R94 R100,R105	806920	4	Resistor, Metal Film, 75kΩ, 0.3W ±0.1%	18612	V53-1
R91,R102	801402	2	Resistor, Composition 820Ω 1/4W ±5%	01121	CB8215
R92,R103	804966	2	Resistor, Composition, 3MΩ, 1/4W ±5%	01121	CB3055
R93,R104 R116,R157 R204,R275 R283	806911	7	Potentiometer, miniature, 50kΩ	32997	3299W-1-503
R95,R106	807327	2	Resistor, Wirewound, 250kΩ ±0.1% 10 ppm	11880	MPC-1A
R96,R107	807183	2	Resistor, Metal Film, 75kΩ 1/4W ±2%	16299	C4
R97,R108 R156	801394	3	Resistor, Composition, 130kΩ, 1/4W ±5%	01121	CB1345
R110,R[illegible]	807[illegible]85	1	Resistor, Metal Film, 7.5kΩ, 1/8 W ±1%	MIL-R 10509	RN55E7501F

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R111	807588	1	Resistor, Metal Film 10KΩ, 1/8W, ±1% 25PPM	MIL-R-10509	RN55E1002F
R115	807591	1	Resistor, Metal Film 46.4KΩ, 1/8W, ±1%	MIL-R-10509	RN55D-1103F
R119	807587	1	Resistor, Metal Film 93.1KΩ, 1/8W, ±1%	MIL-R-10509	RN55E9312F
R133,R160 R[illegible],R189 R279,R290	801636	5	Resistor, Composition 20KΩ, 1/4W, ±5%	01121	CB2035
R139,R140 R145,R146 R152,R153	806544	6	Resistor, Metal Film 20KΩ, 1/8W, ±1%	16299	NC-4
R142,R200 R203,R225 R286	802232	5	Resistor, Composition 1.5KΩ, 1/4W, ±5%	01121	CB1525
R155	807341	1	Resistor, Composition 36Ω, 1/4W, ±5%	01121	CB3605
R158	802084	1	Resistor, Composition 240KΩ, 1/4W, ±5%	01121	CB2445
R159,R201 R211,R236	801397	4	Resistor, Composition 5.1KΩ, 1/4W, ±5%	01121	CB5125
R161	807197	1	Potentiometer, Film 5KΩ	32997	3299W-1-502
R169	802083	1	Resistor, Composition 82KΩ, 1/4W, ±5%	01121	CB8235
R174,R176	807177	2	Resistor, Metal Film 390Ω, 1/4W, ±2%	16299	C4
R175,R177	806913	2	Potentiometer,Miniature 200Ω	32997	3299W-1-201
R186	807592	1	Resistor, Metal Film 110K, 1/8W, ±1%	MIL-R 10509	RN55D1103-F
R187	804312	1	Resistor, Composition 750K, 1/4W, ±5%	01121	CB7545

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT	MFR PART NO.
R178	806541	1	Resistor, Metal Film 2KΩ, 1/4W, ±2%	16299	C4
R179	804311	1	Resistor, Metal Film 3.9KΩ, 1/4W, ±2%	16299	C0-7
R180,R221 R232	806910	3	Potentiometer, Miniature 2KΩ	32997	3389P-1-202
R181	806928	1	Resistor, Composition 1.0Ω, 5W, ±5%	44655	995-5B-4530
R182,R195 R202,R226 R247,R254 R277,R288	803388	8	Resistor, Composition 3.3KΩ, 1/4W, ±5%	01121	CB3325
R184	800856	1	Resistor, Compaosition 150KΩ, 1/2W, ±5%	01121	EB1545
R185	806718	1	Resistor, Metal Film 5.6KΩ, 1/8W, ±1%	16299	NC-4
R R231	806931	1	Resistor, Metal Film 93.1KΩ, 1/8W, ±1%	16299	NC-4
R188,R198 R199,R218 R246,R248 R249,R293 R294	801395	9	Resistor, Composition 6.2KΩ, 1/4W, ±5%	01121	CB6225
R190,R238	804400	2	Resistor, Composition 270KΩ, 1/4W, ±5%	01121	CB2745
R191,R193 R278,R284	802757	4	Resistor, Composition 150KΩ, 1/4W, ±5%	01121	CB1545
R192,R250	802730	2	Resistor, Composition 1MΩ, 1/4W, ±5%	01121	CB1055
R196,R197 R267	803784	3	Resistor, Composition 10Ω, 1/4W, ±5%	01121	CB1005
R208	806239	1	Resistor, Metal Film 150KΩ, 1/4W, ±2%	16299	C07
R220,R223	802081	2	Resistor, Composition 39KΩ, 1/4W, ±5%	01121	CB3935
R222	802191	1	Resistor, Composition 2.7KΩ, 1/4W, ±5%	01121	CB2725

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R224	803784	1	Resistor, Composition 10Ω, 1/4W, ±5%	01121	CB1005
R229	806936	1	Resistor, Metal Film 22.1KΩ, 1/8W, ±1%	16299	NC-4
R234	807112	1	Resistor, Metal Film 43KΩ, 1/4W, ±2%	16299	C4
R235	807181	1	Resistor, Metal Film 15KΩ, 1/4W, ±2%	16299	C4
R239,R240 R241,R289	801986	4	Resistor, Composition 100KΩ, 1/4W, ±5%	01121	CB1045
R258	803240	1	Resistor, Carbon 91KΩ, 1/4W, ±5%	01121	CB9135
R259	802182	1	Resistor, Carbon 22KΩ, 1/4W, ±5%	01121	CB2235
R269	805190	1	Resistor, Composition 5.6KΩ, 1/4W, ±5%	NAI	
R271	807102	1	Resistor, Composition 7.5MΩ, 1/4W, ±5%	01121	CB7555
R274,R291	803389	2	Resistor, Composition 10MΩ, 1/4W, ±5%	01121	CB1065
R272	806930	1	Resistor, Metal Film 2.61KΩ, 1/8W, ±1%	16299	NC-4
R273	807205	1	Resistor, Metal Film 39KΩ, 1/4W, ±2%	16299	C4
R276	804297	1	Resistor, Composition 2.2MΩ, 1/4W, ±5%	01121	CB2255
R282	807590	1	Resistor, Metal Film 2.49KΩ, 1/8W, ±1%	MIL-R-10509	RN55E249-1F
R287	801399	1	Resistor, Composition 430Ω, 1/4W, ±5%	01121	CB4315
R296,R297	807329	2	Resistor, Metal Film 470Ω, 1/4W, ±2%	16299	C4
R299	802190	1	Resistor, Composition 270Ω, 1/4W, ±5%	01121	CB2715

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R300,R285	801981	2	Resistor, Composition 100Ω, 1/4W, ±5%	01121	CB1015
R302	807467	1	Resistor, Temp. Sens. 82Ω, ±10%	01295	TG 1/8 82Ω 10%
R306	807584	1	Resistor, Metal Film 2.0K, 1/8W, ±1%	MIL-R-10509	RN55E-2001F
R307	807586	1	Resistor, Metal Film 22.1K, 1/8W, ±1%	MIL-R-10509	RN55E-2212F
R308	805916	1	Resistor, Film 86.6KΩ, 1/4W, ±1%	MIL-R-10509/2	RN65C-8662F
R309	804301	1	Resistor, Metal Film 91KΩ, 1/4W, ±2%	16299	C0-7
R310		1	Resistor, Metal Film Select at Test From		
	807595		2.87KΩ, 1/8W, ±1%	MIL-R-10509	RN55D-2871F
	807284		4.42KΩ, 1/10W, ±1%	MIL-R 10509	RN55D-4421F
	807596		6.04KΩ, 1/8W, ±1%	MIL-R-10509	RN55D-6041F
S1	205686	1	Switch Range Module 6-Pos	NAI	
S3	205685	1	Switch Function Module 4-Pos	NAI	
S4	806675	1	Switch, 115V-230V	79727	GF-326UL
T1	205502	1	Transformer, Power	NAI	
T2	783594-1	1	500KΩ Broadband Reference Isolated Trans.	NAI	
V1	806972	1	Raysistor	49956	CK1121
Z1,Z33,Z40	804344	3	Integrated Circuit	07263	U6A9936-59X
Z3,Z29,Z30	804458	3	Integrated Circuit	04713	U6A9949-59X
Z4	806962	1	Integrated Circuit	18324	SP357A

MAIN BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
Z5,Z6,Z8	806952	3	Integrated Circuit	01295	SN7426N
Z7,Z11,Z14 Z16	807478	4	Operational Amplifier 301A Selected		
Z19,Z44 Z48	804069	3	Operational Amplifier 709C	07263	709C
Z12	806253	1	Operational Amplifier 741C Selected		
Z13,Z15,Z17 Z35,Z47	806347	5	Operational Amplifier	12040	LM301A
Z20,Z21,Z23 Z24,Z25	805744	5	Rectifier	30857	VE-48
Z22	806969	1	Rectifier	30857	VH-148
Z26,Z27	806946	2	Integrated Circuit Voltage Regulator	12040	LM309K
Z28	806947	1	Integrated Circuit Voltage Regulator	04713	MC1723/CG
Z31,Z32,Z39 Z43	805026	4	Integrated Circuit	07263	U6A9946-59X
Z36,Z41,Z45 Z46	806051	4	Operational Amplifier 741C	12040	741C
Z38	804939	1	Integrated Circuit	04713	U6A9937-59X
Z50	805456	1	Integrated Circuit	07263	U6A960159X
Z51,Z56	806504	2	Integrated Circuit	01295	U6A9N2059X
Z52	806505	1	Integrated Circuit	01295	U6A9N0459X
Z53	806948	1	Integrated Circuit	07263	U6A939259X
Z54,Z57	806122	2	Integrated Circuit	01295	U6A9N1059X
Z55,Z58,Z60	804883	3	Integrated Circuit	01295	U6A9N0059X
Z62,Z9,Z10 Z18	807428	4	Operational Amplifier LM318H	12040	LM318H

MAIN BOARD

SINGLE FREQUENCY INSTRUMENT (MODEL 220)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
CR69	802924	1	Diode, 1N3069	07263	1N3069
Q1	805059	1	Transistor, 2N2906	NAI	
R14,R15,R16	801985	3	Resistor, Composition 51KΩ, 1/4W, ±5%	01121	CB5135
R267	803784	1	Resistor, Composition 10Ω, 1/4W, ±5%	01121	CB1005
R299	802190	1	Resistor, Composition 270Ω, 1/4W, ±5%	01121	CB2715

MULTI-FREQUENCY INSTRUMENT (MODEL 225)

CR10,CR30 CR41,CR42 CR43,CR69	802924	6	Diode, 1N3069	07263	1N3069
CR38	806330	1	Diode, 1N914		
J9,J10,J11	807212	1 2 3	2 Frequency Connector 3 Frequency Connector 4 Frequency Connector	16512	HC200147
Q1 thru Q4	805059	4	Transistor, 2N2906	NAI	
Q34	804360	1	Transistor, 2N4360	07263	2N4360
R5,R6,R7	802190	3	Resistor, Composition 270Ω, 1/4W, ±5%	01121	CB2715
R14,thru R22,R31 R167,R168	801985	12	Resistor, Composition 51KΩ, 1/4W, ±5%	01121	CB5135
R260	803673	1	Resistor, Composition 300Ω, 1/4W, ±5%	01121	CB3315
Z2	806952	1	Integrated Circuit SN7426N	01295	SN7426N

MAIN BOARD

ANGLE MODE & 45° PHASE ADJUST (OPTION 01)

DESIGNATION	PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
CR3,CR71	802924	2	Diode, 1N3069	07263	1N3069
CR36	806330	1	Diode, 1N914	NAI	
K2	806971	1	Relay	MFR 3	530-4-1A
Q19	806949	1	Transistor, [illegible]	[illegible]	[illegible]
Q23	805059	1	Transistor, 2N2906	NAI	
Q29	803662	1	Transistor, 2N3819	01295	2N3819
R44	806544	1	Resistor, Metal Film, 20kΩ 1/8W ±1%	16299	NC4
R49	807332	1	Resistor, Metal Film 150kΩ, 1/4W ±1%	16299	NC4
R50,R149	806911	2	Potentiometer, Miniature 50kΩ ±10%, 25-turn	32997	3299W503
R121,R172	806931	2	Resistor, Metal Film 93.1kΩ, 1/8W ±1%	16299	NC4
R125	801004	1	Resistor, Composition 1.0kΩ, 1/4W ±5%	01121	CB1025
R126	803388	1	Resistor, Composition 3.3kΩ, 1/4W ±5%	01121	CB3325
R131	8022321	1	Resistor, Composition 1.5kΩ, 1/4W ±5%	01121	CB1525
R132	803784	1	Resistor, Composition,10Ω 1/4W ±5%	01121	CB1005
R134	807043	1	Potentiometer, 10kΩ ±5% 10ppm	18612	1202LB-1
R148	806936	1	Resistor, Metal Film, 22.1kΩ, 1/8W ±1%	16299	NC4
R261	806743	1	Resistor, Metal Film,33kΩ 1/8W ±2%	16299	NC4
R263 thru R266	801985	4	Resistor, Composition,51kΩ 1/4W ±5%	01121	CB5135
S2	807203	1	Switch, Reference (in-out)	31918	2XD15-2μGR
S3	807037	1	Switch, Function,6-pos.	31918	6XD15-2μGR
Z34	804807	1	Integrated Circuit	07263	U6A900059X
Z61	806051	1	Operational Amp., 741C	12040	741C

MAIN BOARD

LOCAL CONTROL ONLY
(Use in Absence of Option 03)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R123,R124 R281	803784	3	Resistor, Composition, 10Ω, 1/4W ±5%	01121	CB1005

MAIN BOARD

AUTO RANGING (OPTION 02)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
Q40	806949	1	Transistor, BC-338	03445	BC-338
R205	803388	1	Resistor, Composition, 3.3kΩ 1/4W ±5%	01121	CB3325
R206	802232	1	Resistor, Composition, 1.5kΩ 1/4W ±5%	01121	CB1525
R207	801395	1	Resistor, Composition, 6.2kΩ 1/4W ±5%	01121	CB6225
R208	806239	1	Resistor, Metal Film, 150KΩ 1/4W ±2%	16299	C07
R209, R210	806911	2	Potentiometer, Miniature 50kΩ ±10%, 25-turn	32997	3299W-503
S1	807039	1	Switch, Range, 7-position	31918	7XD15-2μ-GR
Z34	804807	1	Integrated Circuit	07263	U6A900059X
Z37	804833	1	Integrated Circuit	07263	U6B930059X
Z42	806051	1	Operational Amplifier, 741C	12040	741C

REMOTE CONTROL & DIGITAL OUTPUT (OPTION 03)

	500872	1	Cable Assembly (Brown) 16 wire	NAI	
	205569	1	Jumper Wire	NAI	

MAIN BOARD

NON-ISOLATION SIGNAL FRONT END
(Use in Absence of Options 04 and 05)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C9	806086	1	Capacitor, Ceramic 0.1uf, 25V, +80-20%	72982	5815000Y-5U0104Z
CR39,CR40	806330	2	Diode, 1N914	NAI	
CR44	804416	1	Diode, Zener, 6.8V	04713	1N4736A
Q54,Q55	806213	2	Transistor, 2N5246	01295	2N5246
R33	802188	1	Resistor, Composition 4.3K, 1/4W, ±5%	01121	CB4325
R36	807231	1	Resistor, Wirewound 27K, 9W, ±5%	91637	CW7

MAIN BOARD - OPTION 04

SIGNAL TRANSFORMER ISOLATION — SIGNAL FRONT END

DESIGNATION	PART NO.	QTY	DESCRIPTION	IDENT.	PART NO.
C2	806970	1	Capacitor, Trimmer, 0.25-1.5pf	74970	2730001002
C3	807213	1	Capacitor, Polystyrene, 0.011µF, 100V ±2%	84171	1PTL113G
C4	802426	1	Capacitor, Mica, 2500pf 500V ±10%	72136	DM-19-252K
C5,C6	802572	2	Capacitor, Polystyrene 22pf, 500V ±5%	88557	CPR-22J
C9	806086	1	Capacitor, Ceramic 0.1µF, 25V +80, -20%	72982	5815000X5-U0104Z
C12	802333	1	Capacitor, Fixed Mica, 910pf, 500V ±5%	72136	DM-19-911J
CR2	802924	1	Diode, 1N3069	07263	1N3069
CR39,CR40	806330	4	Diode, 1N914	NAI	
CR44	804416	1	Diode, Zener, 6.8V	04713	1N4736A
K1	808020	1	Relay	95073	12 HPCG1C
Q54,Q55	806213	2	Transistor, 2N5246	01295	2N5246
R32	807342	1	Resistor, Metal Film, 10MΩ, ±1%, 25ppm	03888	PME64T9
R33	802188	1	Resistor, Composition 4.3kΩ, 1/4W ±5%	01121	CB4325
R34	806923	1	Resistor, Metal Film 9.9kΩ, 0.3W ±0.1%	18612	V53-1
R35	806913	1	Potentiometer, 200Ω,25-turn	32997	3299W201
R36	807231	1	Resistor, Wirewound, 27kΩ 9W ±5%	91637	CW-7
R40	803389	1	Resistor, Composition 10MΩ, 1/4W ±5%	01121	CB1065
R262	801981	1	Resistor, Composition 100Ω, 1/4W ±5%	01121	CB1015
R298	803784	1	Resistor, Composition 10Ω, 1/4W ±5%	01121	CB1005

MAIN BOARD - OPTION 05

SIGNAL BROADBAND ISOLATION

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
T3	783594-2	1	10 Meg Ω Broadband Signal Isolation Transformer	NAI	

REPLACEMENT PARTS LIST

A/D BOARD (PL-783591)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C2,C4,C12 C13,C19,C20 C21,C22,C26 C27	806086	10	Capacitor, Fixed Ceramic, 0.1μf, 25V +80 -20%	72982	5815000Y-5U0104Z
C3,C7	802425	2	Capacitor, Fixed Mica, 1500pf 500V ±10%	72136	DM19152K
C5,C8,C9 C10	807169	4	Capacitor, Aluminum Electrolytic, 1.0μf, 50V -0 +150%	24138	PCD1PA50
C6,C11,C16 C23,C24	806883	5	Capacitor, Fixed Ceramic 150pf, 500V ±10%	72982	831000X5-F0151K
C14,C15	800880	2	Capacitor, Fixed Ceramic 1000pf, 600V	72982	80800250-102P
C17,C18	805623	2	Capacitor, Fixed Ceramic 500pf, 1000V ±10%	72982	831000X5-F0501K
C28,C42,C48	806719	3	Capacitor, Fixed Ceramic 33pf, 1000V ±5%	72982	831000U2-J0330J
C29	806903	1	Capacitor, Polycarbonate 1.0μf, 50V ±10%	14752	W625B1A-105K
C31,C32	806885	3	Capacitor, Fixed Ceramic 22pf, 1000V ±5%	72982	831000U2-J0220J
C33,C34,C40 C41,C43,C44 C46,C47,C49 C50	803406	10	Capacitor, Fixed Ceramic .01μf, 25V +80 -20%	72982	5835000Y-5U103Z
CR1 thru CR5,CR8, CR9,CR17 CR22 thru CR29	802924	13	Diode, 1N3069	07263	1N3069

A/D BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
CR12	806957	1	Diode, 1N937	04713	1N937
CR13	806958	1	Diode, 1N5234B	04713	1N5234B
J1,J2,J4	807107	3	Header	76381	3429-2002
K1,K2	806959	2	Relay, 530-4-1C	MFR 3	530-4-1C
L1 thru L8	804836	8	Choke, 33μh	76493	9230-56
Q1	807535	1	Transistor, 2N4852	04713	2N4852
Q2,Q3,Q6 Q7,Q20	804088	5	Transistor, 2N4123	04713	2N4123
Q4,Q5	806944	2	Transistor, TIS101	01295	TIS101
Q10,Q11	805808	2	Transistor, TIS75	01295	TIS75
Q12,Q23,Q26	803662	3	Transistor, 2N3819	01295	2N3819
Q17,Q18	805059	2	Transistor, 2N2906	NAI	
Q29,Q30	806949	3	Transistor, BC-338	03445	BC-338
R3	806722	1	Potentiometer, Cermet, 5kΩ	32997	3389P5K
R4	801983	1	Resistor, Composition, 5.6kΩ, 1/4W ±5%	01121	CB5625
R26,R27, R140,R165	801006	4	Resistor, Composition 10kΩ, 1/4W ±5%	01121	CB1035

A/D BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
R5,R8,R28 R67,R123, R150	801981	6	Resistor, Composition, 100Ω 1/4W ±5%	01121	CB1015
R6,R22,R25 R72	801397	4	Resistor, Composition, 5.1kΩ, 1/4W ±5%	01121	CB5125
R9	803236	1	Resistor, Composition 300Ω, 1/4W ±5%	01121	CB3015
R10,R134 R156	801094	3	Resistor, Composition 2kΩ, 1/4W ±5%	01121	CB2025
R11	802227	1	Resistor, Composition 16kΩ, 1/4W ±5%	01121	CB1635
R12,R35,R39, R54,R58,R59 R63,R66	801409	3	Resistor, Composition, 3.9kΩ, 1/4W ±5%	01121	CB3925
R13	806973	1	Resistor, Composition, 2Ω 1/2W ±5%	01121	EB2005
R14,R17,R19 R21,R42, R130,R137, R159,R162	802730	9	Resistor, Composition, 1MΩ 1/4W ±5%	01121	CB1055
R15,R20	801638	2	Resistor, Composition, 47kΩ 1/4W ±5%	01121	CB4735
R16,R33,R85 R102,R138, R142,R163, R166	802757	8	Resistor, Composition, 150kΩ, 1/4W ±5%	01121	CB1545
R18	802193	1	Resistor, Composition, 75kΩ 1/4W ±5%	01121	CB7535
R23	802189	1	Resistor, Composition, 6.8kΩ, 1/4W ±5%	01121	CB6825

A/D BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R24,R65,R169	801395	3	Resistor, Composition 6.2kΩ, 1/4W ±5%	01121	CB6225
R29	802082	1	Resistor, Composition, 62kΩ, 1/4W ±5%	01121	CB6235
R30,R31	801396	2	Resistor, Composition 30kΩ, 1/4W ±5%	01121	CB3035
R32	802903	1	Resistor, Composition 180kΩ, 1/4W ±5%	01121	CB1845
R34,R126 R143,R147 R168	806911	5	Potentiometer, Miniature, 50kΩ ±10%	32997	3299W-503
R122,R149	801408	4	Resistor, Composition, 2.4kΩ, 1/4W ±5%	01121	CB2425
R36,R55	802256	2	Resistor, Composition, 27kΩ, 1/4W ±5%	01121	CB2735
R37,R56	801004	2	Resistor, Composition 1kΩ, 1/4W ±5%	01121	CB1025
R38,R57	801407	2	Resistor, Composition 4.7kΩ, 1/4W ±5%	01121	CB4725
R40	806937	1	Resistor, Metal Film 232kΩ, 1/4W ±2%	16299	C4
R43	801985	1	Resistor, Composition 51kΩ, 1/4W ±5%	01121	CB5135
R44	801393	1	Resistor, Composition 24kΩ, 1/4W ±5%	01121	CB2435
R64,R66	804212	2	Resistor, Composition 160Ω, 1/4W ±5%	01121	CB1615
R68	806942	1	Potentiometer, Miniature 2kΩ	18612	1203P2K

A/D BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
R71	806939	1	Resistor, Metal Film, 750Ω 1/4W, ±2%	16299	C4
R73	807166	1	Resistor, Metal Film, 16.5kΩ, 1/4W ±1%	16299	C4
R119,R144	802081	2	Resistor, Composition 39kΩ, 1/4W ±5%	01121	CB3935
R120,R145	801721	2	Resistor, Composition 12kΩ, 1/4W ±5%	01121	CB1235
R121,R127 R146,R152	806932	4	Resistor, Metal Film, 5kΩ .3W ±.1%	18612	V53-1
R124,R151	802084	2	Resistor, Composition, 240kΩ, 1/4W ±5%	01121	CB2445
R125,R148	801987	2	Resistor, Composition, 390kΩ, 1/4W ±5%	01121	CB3945
R128,R153	806913	2	Pot,Miniature, 200Ω ±10%	32997	3299W201
R129,R154	806919	2	Resistor, Metal Film, 20kΩ .3W ±.1%	18612	V53-1
R131,R160	807323	2	Resistor, Metal Film,43.5kΩ .3W ±.1%	18612	V53-1
R132,R161	807164	2	Pot,Miniature, 500Ω ±10%	32997	3299W501
R133,R155	802904	2	Resistor, Composition, 36kΩ, 1/4W ±5%	01121	CB3635
R135,R157	802226	2	Resistor, Composition, 200Ω, 1/4W ±5%	01121	CB2015
R136,R158	806933	2	Resistor, Metal Film,40kΩ .3W ±.1%	18612	V53-1
R139,R164	807165	2	Resistor, Composition,910Ω 1/4W ±5%	01121	CB9115

A/D BOARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R141,R167	804062	2	Resistor, Composition, 43Ω 1/4W ±5%	01121	CB4305
Z4	805032	1	Integrated Circuit	07263	U6A993059X
Z5,Z7,Z9	804344	3	Integrated Circuit	07263	U6A993659X
Z6,Z8,Z26 Z40	805026	4	Integrated Circuit	07263	U6A994659X
Z10,Z15,Z39	804458	3	Integrated Circuit	07263	U6A994959X
Z11,Z12,Z13 Z14,Z16,Z19	804883	6	Integrated Circuit	07263	U6A9N0059X
Z20,Z21	806961	2	Integrated Circuit	01295	SN74121N
Z22	805807	1	Integrated Circuit	07263	U6A996259X
Z23	807517	1	Operational Amplifier LM301A	12040	LM301A
Z24,Z27,Z29 Z30,Z31,Z34 Z35,Z37	806051	8	Operational Amplifier UC4-741C	12040	UC4-741C
Z25	806347	1	Operational Amplifier LM301A Selected	12040	LM301A
Z33	803802	1	Integrated Circuit	07263	U6A993259X
Z36,Z38	807478	2	Operational Amplifier LM301A Selected	NAI	

A/D BOARD

ANGLE MODE & ±45° PHASE ADJUST (OPTION 01)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1	805623	1	Capacitor, Ceramic Disc, 1000V 500pf ±10%	72982	831000X5F-0501K
C25	806883	1	Capacitor, Ceramic Disc, 150pf 1000V ±10%	72982	831000X5F-220J
C30	806885	1	Capacitor, Ceramic Disc, 22pf 1000V ±5%	72982	831000U2-J0220J
C37, C38	803406	2	Capacitor, Ceramic Disc, .01μf 25V +80% -20%	72982	5835000Y5-103Z
CR6, CR11, CR14 thru CR16 CR18 thru CR21	802924	9	Diode, 1N3069	07263	1N3069
K3, K4	806960	2	Relay	MFR 3	360-4-2A
Q8, Q15	804088	2	Transistor, 2N4123	04713	2N4123
Q9	805808	1	Transistor, TIS75	01295	TIS75
Q14, Q28	803662	2	Transistor, 2N3819	01295	2N3819
Q16, Q19	805059	2	Transistor, 2N2906	NAI	4121N
Q21, Q22, Q27	806949	3	Transistor, BC-888	73445	BC-888
Q24, Q25	804360	2	Transistor, 2N4360	07263	2N4360
R1, R76	802189	2	Resistor, Composition, 6.8kΩ, 1/4W ±5%	01121	CB6825
R2	801395	1	Resistor, Composition 6.2kΩ, 1/4W ±5%	01121	CB6225
R41	802730	1	Resistor, Composition, 1MΩ 1/4W ±5%	01121	CB1055
R47	801982	1	Resistor, Composition, 1.2kΩ, 1/4W ±5%	01121	CB1225
R48, R79	806911	2	Potentiometer, Miniature 50kΩ ±10%	32997	3299W503
R49, R52, R53 R78, R80, R89 R101, R110	802757	8	Resistor, Composition 150kΩ, 1/4W ±5%	01121	CB1545

A/D BOARD - OPTION 01

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
R50,R51 R116	801985	3	Resistor, Composition, 51kΩ, 1/4W ±5%	01121	CB5135
R59	801408	1	Resistor, Composition, 2.4kΩ, 1/4W ±5%	01121	CB2425
R60	802256	1	Resistor, Composition, 27kΩ, 1/4W ±5%	01121	CB2735
R61	801004	1	Resistor, Composition, 1kΩ, 1/4W ±5%	01121	CB1025
R62	801407	1	Resistor, Composition, 4.7kΩ, 1/4W ±5%	01121	CB4725
R63	801409	1	Resistor, Composition, 3.9kΩ, 1/4W ±5%	01121	CB3925
R69	807165	1	Resistor, Composition, 910Ω, 1/4W ±5%	01121	CB9135
R77	804062	1	Resistor, Composition, 43Ω, 1/4W ±5%	01121	CB4305
R81	806093	1	Resistor, Composition, 470kΩ, 1/4W ±5%	01121	CB4745
R82	801008	1	Resistor, Composition, 9.1kΩ, 1/4W ±5%	01121	CB9125
R83	807168	1	Resistor, Metal Film, 22.1kΩ, 1/4W ±1%	16299	C4
R84,R92	807166	2	Resistor, Metal Film, 16.5kΩ, 1/4W ±1%	16299	C4
R86,R95 R115	806724	3	Potentiometer, Cermet, 10kΩ, ±10%	32997	3389P
R87,R96	801636	2	Resistor, Composition, 20kΩ, 1/4W ±5%	01121	CB2035

A/D BOARD - OPTION 01

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR. PART NO.
R88,R97	801406	2	Resistor, Composition, 3kΩ, 1/4W ±5%	01121	CB3025
R90	804324	1	Resistor, Composition, 750kΩ, 1/4W ±5%	01121	CB7545
R91	802255	1	Resistor, Composition, 11kΩ 1/4W ±5%	01121	CB1135
R94	807167	1	Resistor, Metal Film, 38.3kΩ, 1/4W ±1%	16299	C4
R111	801987	1	Resistor, Composition, 390kΩ, 1/4W ±5%	01121	CB3945
R112,R113	801983	2	Resistor, Composition, 5.6kΩ, 1/4W ±5%	01121	CB5625
R114	804248	1	Resistor, Composition, 820kΩ, 1/4W ±5%	01121	CB8245
R117	801393	1	Resistor, Composition, 24kΩ, 1/4W ±5%	01121	CB2435
R118	801006	1	Resistor, Composition, 10kΩ, 1/4W ±5%	01121	CB1035
Z1	805026	1	Integrated Circuit, 946	07263	946
Z2,Z3	805807	2	Integrated Circuit, 962	07263	962
Z17	804807	1	Integrated Circuit, U6A900059X	07263	U6A900059X
Z18	806121	1	Integrated Circuit, U6A939059X	07263	U6A939059X
Z27	806639	1	Op. Amp. 741C Selected	07342	741C
Z28	807208	1	Resistor Network Module		
Z31,Z34	806051	2	Op. Amp. 741C	12040	741C

READ-OUT BOARD (PL-783590)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1,C2,C3,C4	805154	4	Capacitor, Ceramic, 0.1μf 25VDC +80-20%	NAI	
C5	807258	1	Capacitor,Mica 91pf,500V±5%	72136	DM15BD910J
DS1	806965	1	Read-Out	07187	SP-751
DS2	806964	1	Read-Out	07187	SP-753
DS3,DS4,DS5 DS6,DS7,DS8 DS9,DS10,DS11 DS12,DS13	806963	11	Lamp	05464	2203-AS25
L1,L2,L3,L4	803823	4	Choke, 33μh	76493	9310-52
J1,J2	807107	2	Header	76381	3429-2002
Q1,Q2,Q3,Q4	806944	4	Transistor, TIS-101	01295	TIS-101
R1,R8,R9, R14	801638	4	Resistor, Composition,47kΩ 1/4W ±5%	01121	CB4735
R2,R4,R5,R6 R7,R10,R11, R12,R13,R15, R16	803553	11	Resistor, Composition, 330kΩ, 1/4W ±5%	01121	CB3345
R3	802082	1	Resistor, Composition 62kΩ, 1/4W ±5%	01121	CB6235
R17,R18,R19 R20	801006	4	Resistor, Composition 10kΩ, 1/4W ±5%	01121	CB1035
R21,R22,R23 R24	800079	4	Resistor, Composition, 2.2kΩ, 1/2W ±5%	01121	EB2225
Z1,Z2,Z3,Z4	806945	4	Integrated Circuit	07187	DD-700
Z5,Z6,Z7,Z8	806149	4	Integrated Circuit	07263	U6B937559X
Z9,Z10,Z11 Z12	806798	4	Integrated Circuit	07263	U7B936059X
Z13	806962	1	Integrated Circuit	18324	SP357A
Z14	804344	1	Integrated Circuit	07263	U6A93659X

REFERENCE ISOLATION BOARD (PL-783601)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1	807240	1	Capacitor, Polycarbonate, 4μf, 50V ±10%	14752	625B1A405K
C2	806970	1	Capacitor, Trimmer, .25-1.5pf, 600V	74970	2730001001
C3	802619	1	Capacitor, Mica, 1pf, 500V ±.5pf	72136	DM15010D
C4	802315	1	Capacitor, Mica, 750pf 300V ±5%	72136	DM15751J
C5	807246	1	Capacitor, Electrolytic 47μf, 35V +100-0%	24138	PCD47PF35
C6,C7	803406	2	Capacitor, Ceramic, .01μf 25V +80-20%	72982	5835
C8,C9	807656	2	Capacitor, Tantalum, 220μf 30V ±20%	56289	109D227X-0030F2
C10	802421	1	Capacitor, Mica, 5pf 500V ±10%	72136	DM15050K
C11	807216	1	Capacitor, Trimmer, 2-8pf 200-350V	72982	538011A-28PF
CR1,CR4 CR5	802924	3	Diode, 1N3069	07263	1N3069
CR2,CR3	804416	2	Diode, 1N4736A	04713	1N4736A
CR6,CR7	803368	2	Diode, 1N4744A	04713	1N4744A
DS1	806963	1	Lamp	24138	2203-A825
K1	806971	1	Relay	MFR 2	530-4-1A
Q1	807247	1	Transistor, 2N5777	24138	2N5777
Q2	803529-2	1	Transistor, SS602-2	NAI	
Q3	804899	1	Transistor, 2N2219	04713	2N2219

REF. ISOLATION BOARD -

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT	MFR PART NO
Q4	804851	1	Transistor, 2N2905	04713	2N2905
R1	802232	1	Resistor, Composition, 1.5kΩ 1/4W ±5%	01121	CB1525
R2	802227	1	Resistor, Composition, 16kΩ 1/4W ±5%	01121	CB1635
R3	801393	1	Resistor, Composition, 24kΩ 1/4W ±5%	01121	CB2435
R4	801408	1	Resistor, Composition, 2.4kΩ 1/4W ±5%	01121	CB2425
R5	806929	1	Resistor, Metal Film, 499kΩ 1/4W ±1%	16299	NC5
R6	806930	1	Resistor, Metal Film, 2.61kΩ 1/8W ±1%	16299	NC4
R7	806931	1	Resistor, Metal Film, 93.1kΩ 1/8W ±1%	16299	NC4
R11,R12	801985	2	Resistor, Composition, 51kΩ 1/4W ±5%	01121	CB5135
R13,R16	801636	2	Resistor, Composition, 20kΩ 1/4W ±5%	01121	CB2045
R14	807227	1	Pot., Trimmer, 1kΩ, 1/2W	32997	3299W1102
R17,R18	801094	2	Resistor, Composition, 2kΩ 1/4W ±5%	01121	CB2035
R19	803784	1	Resistor, Composition, 10Ω 1/4W ±5%	01121	CB1005
R20,R21	801981	2	Resistor, Composition, 100Ω 1/4W ±5%	01121	CB1015
Z1	806506	1	Operational Amplifier, LM310	27014	LM-310

SIGNAL DIRECT MODE BOARD ASSY.
(Use in Absence of Options 04 and 05) PL-783673

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1	807193	1	Capacitor, Polycarbonate .1uf, 400V, ±10%	14752	W625C1E104K
C2	806970	1	Capacitor, Trimmer .25-1.5pf	74970	2730001001
C3	807213	1	Capacitor, Polycarbonate .01luf, 100V, ±2%	84171	1PTL113G
C10,C11	802572	2	Capacitor, Polystyrene 22pf, 500V, ±5%	88557	CPR-22J
C12	802426	1	Capacitor, Mica 2500pf, 500V, ±10%	72136	DM19-252
CR1	802924	1	Diode, 1N3069	07263	1N3069
K1	500885	1	Relay	NAI	
R7	806913	1	Potentiometer, Trimmer 200Ω, 25-turn	32997	3299W201
R6	806923	1	Resistor, Metal Film 9.9K, .3W, ±.1%	18612	V53-1
R5	807342	1	Resistor, Metal Film 10 Meg, ±1%, 25PPM	03888	PME64T9
R22	803784	1	Resistor, Composition 10Ω, 1/4W, ±5%	01121	CB1005
R8	803389	1	Resistor, Composition 10 Meg, 1/4W, ±5%	01121	CB1065
R4	801981	1	Resistor, Composition 100Ω, 1/4W, ±5%	01121	CB1015

OPTION 05

SIGNAL ISOLATION BOARD (PL-783602)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1	807647	1	Capacitor, Mylar .68uf. 400V, ±10%	12406	ZD4A684K
C2	806970	1	Capacitor, Trimmer, .25-1.5pf 600V	74970	2730001001
C3	807213	1	Capacitor, Polystyrene, 0.011µf, 100V ±2%	84171	1PTL113G
C4	806210	1	Capacitor, Ceramic, 820pf 1000V ±20%	MIL-C 11015C	CK60AW821M
C5	807246	1	Capacitor, Electrolytic 47µf, 35V ±100-0%	24138	PCD47PF35
C6,C7	803406	2	Capacitor, Ceramic, 0.01µf 25V +80-20%	72982	5835000Y5-U103Z
C8,C9	807656	2	Capacitor, Tantalum, 220uf, 30V, ±20%	56289	109D227X-0030F2
C10,C11	802572	2	Capacitor, Polystyrene, 22pf 500V ±5%	71590	CPR-22J
C12	802426	1	Capacitor, Mica, 2500pf 500V ±10%	72136	DM-19-252K
C13	801743	1	Cap., Mica 15pf, 500V, ±1pf	72136	DM15-150K
CR1,CR4,CR5	802924	3	Diode, 1N3069	07263	1N3069
CR2,CR3	804416	2	Diode, 1N4736A	04713	1N4736A
CR6,CR7	803368	2	Diode, 1N4744A	04713	1N4744A
CR8	803205	1	Diode, Zener 30V	04713	1N792B
DS1	806963	1	Lamp	24138	2203-A825
K1	500885	1	Relay	NAI	
L1	807649	1	Choke 68uh	83125	DD-68
Q1	807247	1	Transistor, 2N5777	24138	2N5777
Q2	803529-2	1	Transistor, 88602-2	NAI	
Q3	804899	1	Transistor, 2N2219	04713	2N2219

SIGNAL ISOLATION BOARD - OPTION 05

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
Q4	804851	1	Transistor, 2N2905	04713	2N2905
R1	802232	1	Resistor, Composition 1.5KΩ, 1/4W, ±5%	01121	CB1525
R2	802227	1	Resistor, Composition 16KΩ, 1/4W, ±5%	01121	CB1635
R3	801393	1	Resistor, Composition 24KΩ, 1/4W, ±5%	01121	CB2435
R4	804162	1	Resistor, Composition 910Ω, 1W, ±5%	MIL-R 11E	RC32GF911F
R5	807342	1	Resistor, Metal Film 10MΩ, 1/4W, ±1% ±25ppm	03888	PME64T9
R6	806923	1	Resistor, Metal Film 9.9KΩ, .3W, ±.1%	18612	V53-1
R7	806913	1	Potentiometer, Trimmer 200Ω, 1/2W	32997	3299W201
R8	803389	1	Resistor, Composition 10MΩ, 1/4W, ±5%	01121	CB1055
R10	807231	1	Resistor, Wirewound 27KΩ, 9W, ±5%	91637	CW7
R11,R12	801985	2	Resistor, Composition 51KΩ, 1/4W, ±5%	01121	CB5135
R13,R16	801636	2	Resistor, Composition 20KΩ, 1/4W, ±5%	01121	CB2035
R14	807227	1	Potentiometer, Trimmer 1K, 1/2W	32997	3299W1102
R17,R18	801094	2	Resistor, Composition 2KΩ, 1/4W, ±5%	01121	CB2035
R20,R21	801981	2	Resistor, Composition 100Ω, 1/4W, ±5%	01121	CB1015
R22	803784	1	Resistor, Composition 10Ω, 1/4W, ±5%	01121	CB1005
R23	807648	1	Resistor, Wirewound 100Ω, 2.5W, ±5%	91637	CW2C
Z1	806506	1	Operational Amplifier LM310	27014	LM310

35

OPTION 03

REMOTE CONTROL/DIGITAL OUTPUT CARD

(PL-783603)

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1,C2,C3	801240	3	Capacitor, Mica 1000pf, 100V, ±10%	72136	DM-15-102K
C4	807169	1	Capacitor, Aluminum 1uf, 50V, -0 ±100%	24138	PCD1PA50
C5	803408	1	Capacitor, Tantalum 10uf, 10V, ±10%	56289	150D106X-9010B2
C6	801311	1	Capacitor, Tantalum 3.3uf, 35V, ±20%	56289	150D335X-0035B2
CR1	802924	1	Diode 1N3600 (For Ratio Mode -4 Assy. ONLY)	07263	1N3600
J1	807393	1	Connector, 15 Pin	71785	DAM-15P-14
J2	807394	1	Connector, 37 Pin	71785	DCM-37P-A
J3,J5	807107	2	Header	76381	3429-2002
J6	807474	1	Socket	01295	C931602
Q1,Q2	806949	2	Transistor, BC-338	73445	BC-338
Q3,Q4,Q5	803662	3	Transistor, 2N3819	01295	2N3819
R1	802188	1	Resistor, Composition 4.3KΩ, 1/4W, ±5%	01121	CB4325
R2,R3,R4 R5,R6,R9	801395	6	Resistor, Composition 6.2KΩ, 1/4W, ±5%	01121	CB6225
R7		1	Resistor, Factory Trim 2.4MΩ Nom.	NAI	
R10,R11,R12 R13,R14,R15	801985	6	Resistor, Composition 51KΩ, 1/4W, ±5%	01121	CB5135
R16	802226	1	Resistor, Composition 200Ω, 1/4W, ±5%	01121	CB2015
Z1,Z2,Z3,Z7	806837	4	Integrated Circuit, 962	07263	U6A99625DX
Z4,Z5,Z10 Z11,Z12,Z13	805026	6	Integrated Circuit	07263	U6A994659DX
Z6,Z8,Z9 Z16,Z17,Z18 Z19,Z20,Z21	804344	9	Integrated Circuit	07263	U6A993659DX
Z14,Z15	805456	2	Integrated Circuit	07263	U6A960159DX

PARTS LISTINGS

FOR

FREQUENCY RELATED COMPONENTS

MAIN BOARD

400Hz

DESIGNATION	NAI PART NO.	TOTAL QTY.	DESCRIPTION	CODE IDENT.	MFG. PART NO.
C18,65	808065	2	Capacitor, Poly .001μf, 100V, ±1%	84171	1PG102F
C19,64	808073	2	Capacitor, Poly .022μf, 100V, ±1%	84171	1PG223F
C76	806897	1	Capacitor, Polycarb. .022μf, 50V, ±10%	14752	W625B1A223K
C77	807185	1	Capacitor, Polycarb. .047μf, 50V, ±10%	14752	W625B1A473K
C83	807191	1	Capacitor, Polycarb. .0047μf, 50V, ±5%	14752	W625B1A472J
C138,139	807433	2	Capacitor, Mica 180pf, 500V, ±1%	72136	DM15-181F
C175,176	807436	2	Capacitor, Mica 50pf, 500V, ±1%	72136	DM15-500F
R57,60,128, 130	807176	4	Resistor, Metal Film 10kΩ, .3W, ±.1%	75042	Type MAR5 T16 (5PPM/°C)
R58,127	806920	2	Resistor, Metal Film 75K, 200V, ±.1%	75042	Type MAR5 T16 (5PPM/°C)
R59	807184	1	Resistor, Metal Film 240Ω, 1/4W, ±2%	16299	C4
R129	807227	1	Resistor, Variable 1K, 1/2W, 25T	32997	3299W-1-102
R133	801636	1	Resistor, Composition 20K, 1/4W, ±5%	01121	CB2035
R150	801394	1	Resistor, Composition 130K, 1/4W, ±5%	01121	CB1345
R162	807166	1	Resistor, Metal Film 16.5K, 1/4W, ±1%	16299	C4

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400Hz (con't)

DESIGNATION	NAI PART NO.	TOTAL QTY.	DESCRIPTION	CODE IDENT.	MFG. PART NO.
R169	802083	1	Resistor, Composition 82K, 1/4W, ±5%	01121	CB8235
R319	807198	1	Resistor, Variable 100Ω, 1/2W, 25T	32997	3299W-1-101

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FREQUENCY CARD (PL-783599)

DESIGNATED	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C6,7,13,14	806086	4	Capacitor, Ceramic .1uf, 25V, +80 -20%	72982	5815-000-Y5U0104Z
C15,20,23, 29,31,32,33	806890	7	Capacitor, Electrolytic 10uf, 25V, +100 -0%	24138	PCD-10PB-25
C16,19,41	803406	3	Capacitor, Ceramic .01uf, 25V, +80 -20%	72982	5835-000Y-5U103Z
C21,22	806883	2	Capacitor, Ceramic 150pf, 1000V, ±10%	72982	831-000X5-F0151K
C26	802338	1	Capacitor, Mica 39pf, 500V, ±5%	84171	DM15-390K
C39	801365	1	Capacitor, Mica 150pf, 500V, ±5%	72136	DM15-F151J
C40	802421	1	Capacitor, Mica 5pf, 500V, ±10%	72136	DM15-050K
CR1,2,3,6, 9,10	802924	6	Diode, 1N3069	07263	1N3069
CR5,8	807217	2	Diode, 4.3V, 1n5229	04713	1N5229
L1,2,3,4	804836	4	Choke, 33uh	76493	9230-56
Q1,2	804583	2	Transistor, TIS 73	01295	TIS 73
Q3,11	806949	2	Transistor, BC-338	73445	BC-338
Q4	803662	1	Transistor, 2N3819	01295	2N3819
Q5,6,13	805808	3	Transistor, TIS 75	01295	TIS 75
Q7,8	807479	2	Transistor, 2N6002	03508	2N6002
Q9	805061	1	Transistor, 2N2906	04713	2N2906
Q10	804318	1	Transistor, 2N4851	04713	2N4851
Q12	804360	1	Transistor, 2N4360	07263	2N4360

FREQUENCY CARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R7,17	804297	2	Resistor, Composition 2.2MΩ, 1/4W, ±5%	01121	CB2255
R8,18,35,41	807251	4	Potentiometer, Trim 50K, 1/2W, ±10%	32997	3299X-50KΩ
R9,40,50	806239	3	Resistor, Metal Film 150K, 1/4W, ±2%	16299	CO-7
R47	801636	1	Resistor, Composition 20K, 1/4W, ±5%	01121	CB2035
R16,39,51	807344	3	Resistor, Metal Film 43Ω, 1/4W, ±2%	16299	CO-7
R19,22,30, 31,33,34	806544	6	Resistor, Metal Film 20K, 1/8W, ±1%	16299	NC-4
R20,23,24, 26,38	801006	5	Resistor, Composition 10K, 1/4W, ±5%	01121	CB1035
R25	801985	1	Resistor, Composition 51K, 1/4W, ±5%	01121	CB5135
R27,28,48	801094	3	Resistor, Composition 2K, 1/4W, ±5%	01121	CB2025
R29,32	801988	2	Resistor, Composition 15K, 1/4W, ±5%	01121	CB1535
R36	806936	1	Resistor, Metal Film 22.1K, 1/8W, ±1%	16299	NC-4
R37	801394	1	Resistor, Composition 130K, 1/4W, ±5%	01121	CB1345
R42	802084	1	Resistor, Composition 240K, 1/4W, ±5%	01121	CB2445
R43	801397	1	Resistor, Composition 5.1K, 1/4W, ±5%	01121	CB5125
R44	807250	1	Potentiometer, Trimmer 5K, 1/2W, ±10%	32997	3299K-5KΩ
R45	802188	1	Resistor, Composition 4.3K, 1/4W, ±5%	01121	CB4325

FREQUENCY CARD

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
R46	807166	1	Resistor, Metal Film 16.5K, 1/4W, ±1%	16299	C4
R49	803673	1	Resistor, Composition 330Ω, 1/4W, ±5%	01121	CB3315
R52	806931	1	Resistor, Metal Film 93.1K, 1/8W, ±1%	16299	NC-4
R56,53	801721	2	Resistor, Composition 12K, 1/4W, ±5%	01121	CB1235
Z1,2	807428	2	Operational Amplifier LM318H	12040	LM318H
Z3	807517	1	Operational Amplifier 301A	12040	LM301AH
Z4	807478	1	Operational Amplifier 301A Selected	12040	301A
Z5	806952	1	Integrated Circuit	01295	SN7426N

FREQUENCY CARD

4.8KHz

DESIGNATION	NAI PART NO.	TOTAL QTY	DESCRIPTION	CODE IDENT.	MFR PART NO.
C1,C8	807734	2	Capacitor, Mica 10pf, 300V, ±5%	72136	DM5CC100JP 4CR
C2,C9	807434	2	Capacitor, Mica 82pf, 500V, ±1%	72136	DM15-820F
C4,C10	808060	2	Capacitor, Mica 1800pf, 500V, ±1%	72136	DM20FD-182F0-4CR
C24	807283	1	Capacitor, Polycarb 3900pf, 50V, ±10%	14752	W625B1A392K
C25	802236	1	Capacitor, Film 1800pf, 400V, ±10%	56289	192P18294
C27,C28	802165	2	Capacitor, Mica 36pf, 500V, ±5%	72136	SCDM10-360J
C30	802242	1	Capacitor, Mica 330pf, 500V, ±5%	72136	DM15-331J
C34	802216	1	Capacitor, Mica 24pf, 500V, ±5%	72136	DM15-E240J
C35,C36	803417	2	Capacitor, Trim Ceramic 2-8pf	72982	5380060NPO(CO PO)2-8(89R)
R1,5,12,13	807176	4	Resistor, Metal Film 10K, .3W, ±.1%	75042	TYPE MAR5T16 (5PPM/°C)
R2	807655	1	Potentiometer 500Ω	32997	3299X-1-501
R3,R11	806920	2	Resistor, Metal Film 75K, .3W, ±.1%	75042	TYPE MAR5T16 (5PPM/°C)
R6	802083	1	Resistor, Composition 82K, 1/4W, ±5%	01121	CB8235
R10	807296	1	Potentiometer 1K, 1/2W, 25 Turn	32997	3299X1102
R15	801636	1	Resistor, Composition 20K, 1/4W, ±5%	01121	CB2035

FREQUENCY CARD

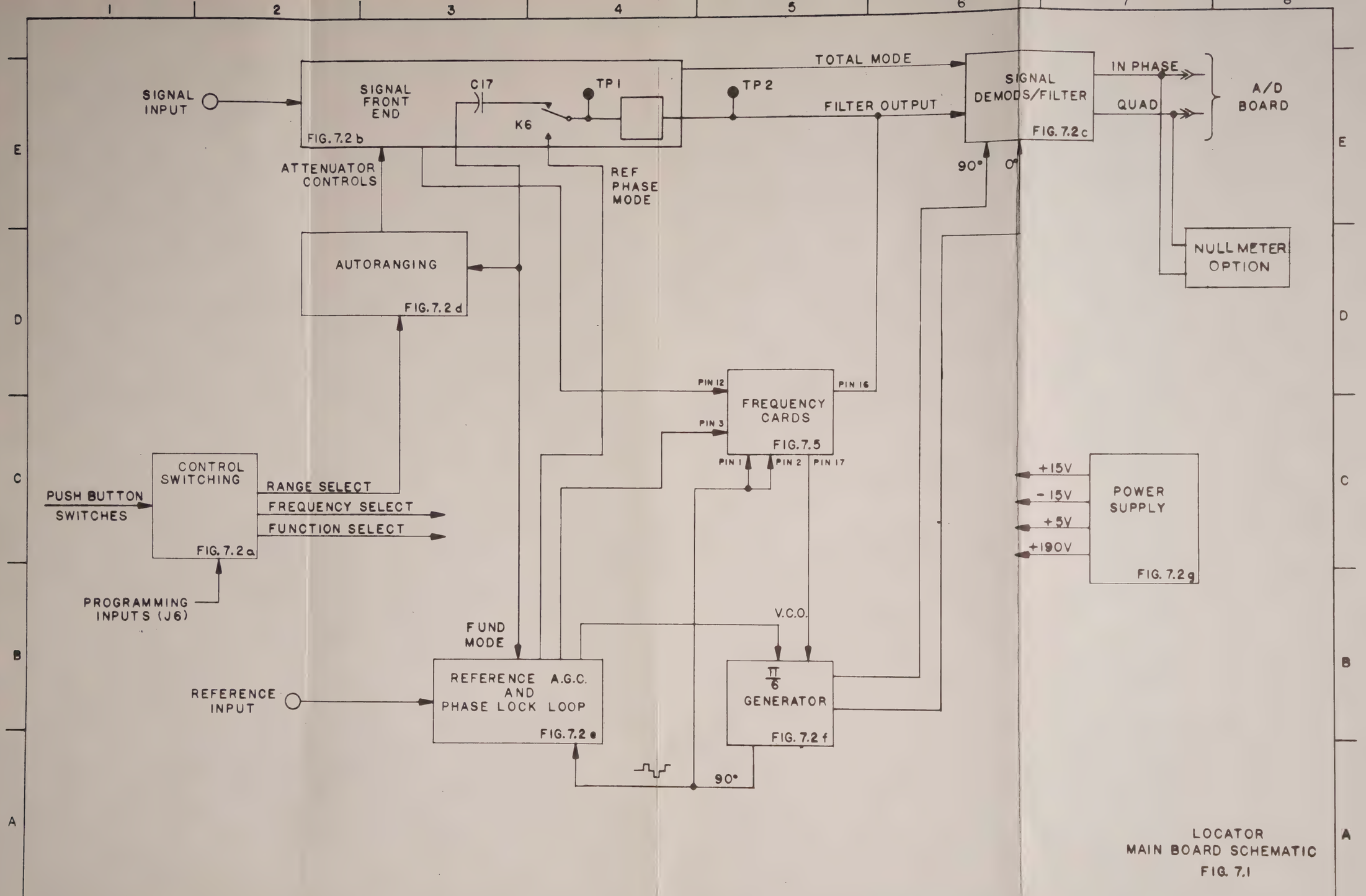
29kHz

DESIGNATION	NAI PART NO.	TOTAL QTY.	DESCRIPTION	CODE IDENT.	MFG. PART NO.
C1,8	807579	2	Capacitor, Mica 15pf, 500V, ±5%	72136	DM15-150-J
C4,10	807440	2	Capacitor, Mica 270pf, 500V, ±1%	72136	DM15-271F
C24	807262	1	Capacitor, Mica 620pf, 500V, ±5%	72136	DM15BD621J
C25	802450	1	Capacitor, Mica 300pf, 500V, ±5%	84171	DM-10-301-J
C27,28	803610	2	Capacitor, Mica 33pf, 500V, ±5%	72136	DM-I0E33J0500 WV4CR
C30	807734	1	Capacitor, Mica 10pf, 500V, ±5%	72136	DM5CC100JP4CR
C34	807264	1	Capacitor, Mica 62pf, 500V, ±5%	72136	DM15BD628J
C35,36	806970	2	Capacitor, Trim .25-1.25pf,Tef.	74970	273-0001-001
R1,5,12,13	807176	4	Resistor, Metal Film 10K, .3W, ±.1%	75042	Type MAR5 T16(5PPM/°C)
R2	807655	1	Resistor, Pot 500Ω, ±10%, 25T	32997	3299X-1-501
R3,11	806920	2	Resistor, Metal Film 75K, .3W, ±.1%	18612	V53-1
R6	802083	1	Resistor, Composition 82K, 1/4W, ±5%	01121	EB1525
R10	807296	1	Resistor, Pot 1K, 1/2W, 25T	32997	3299K-1-102
R15	801636	1	Resistor, Composition 20K, 1/4W, ±5%	01121	CB2035

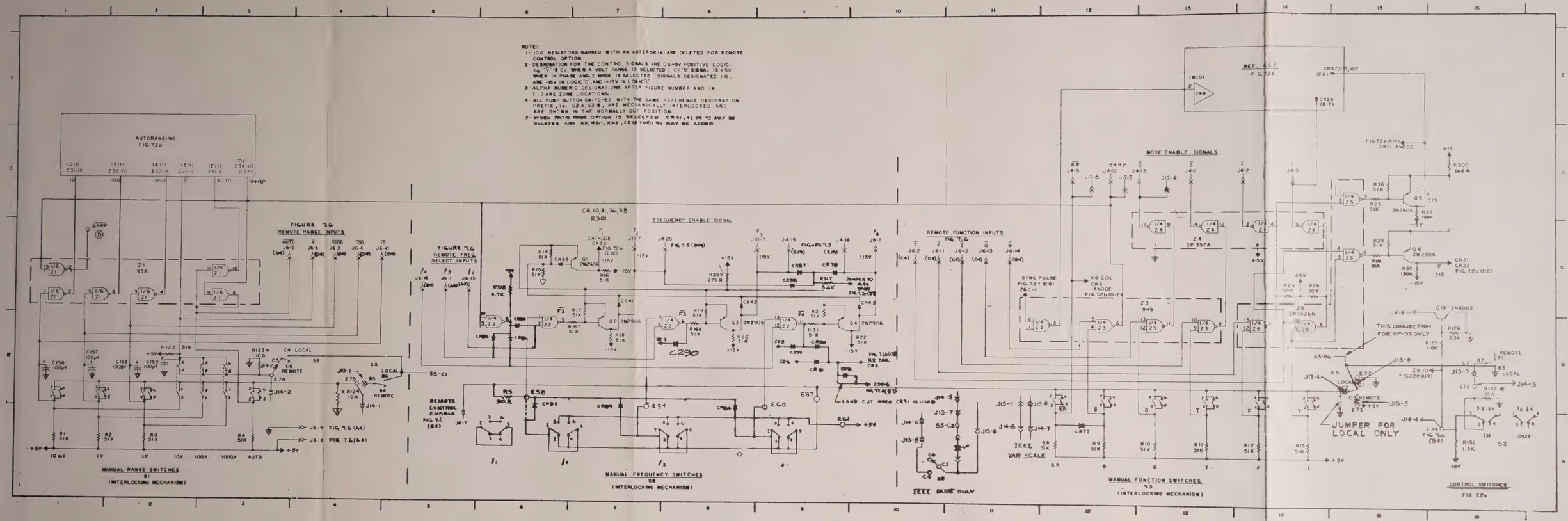
BRUNING 40-135 32372

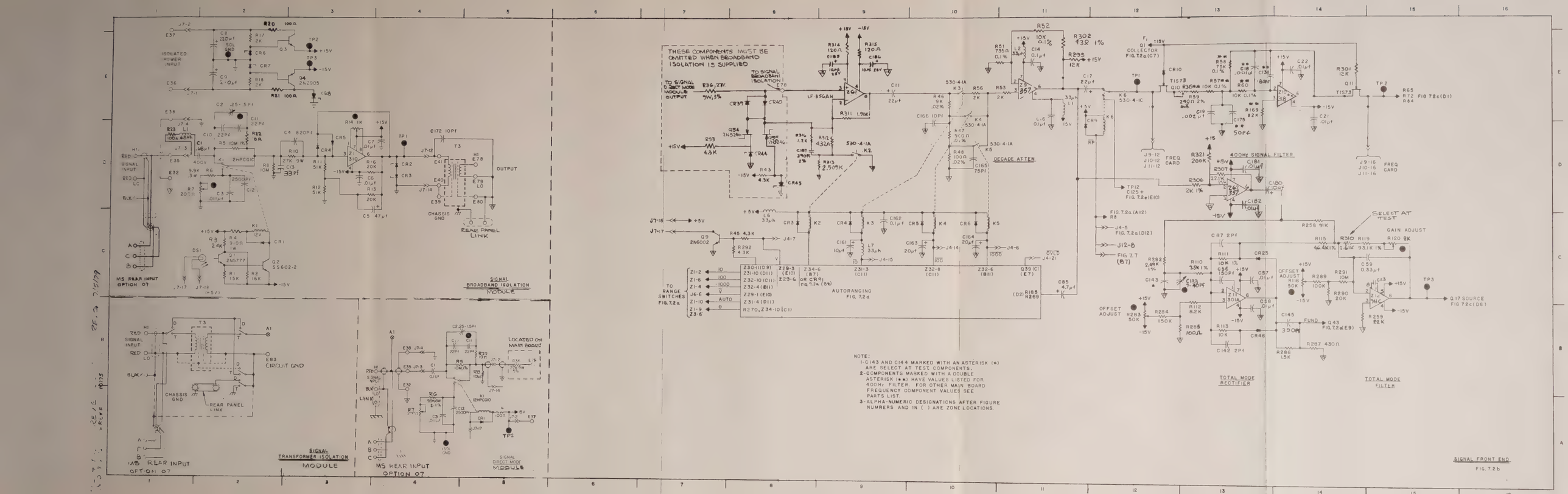
SECTION VIII

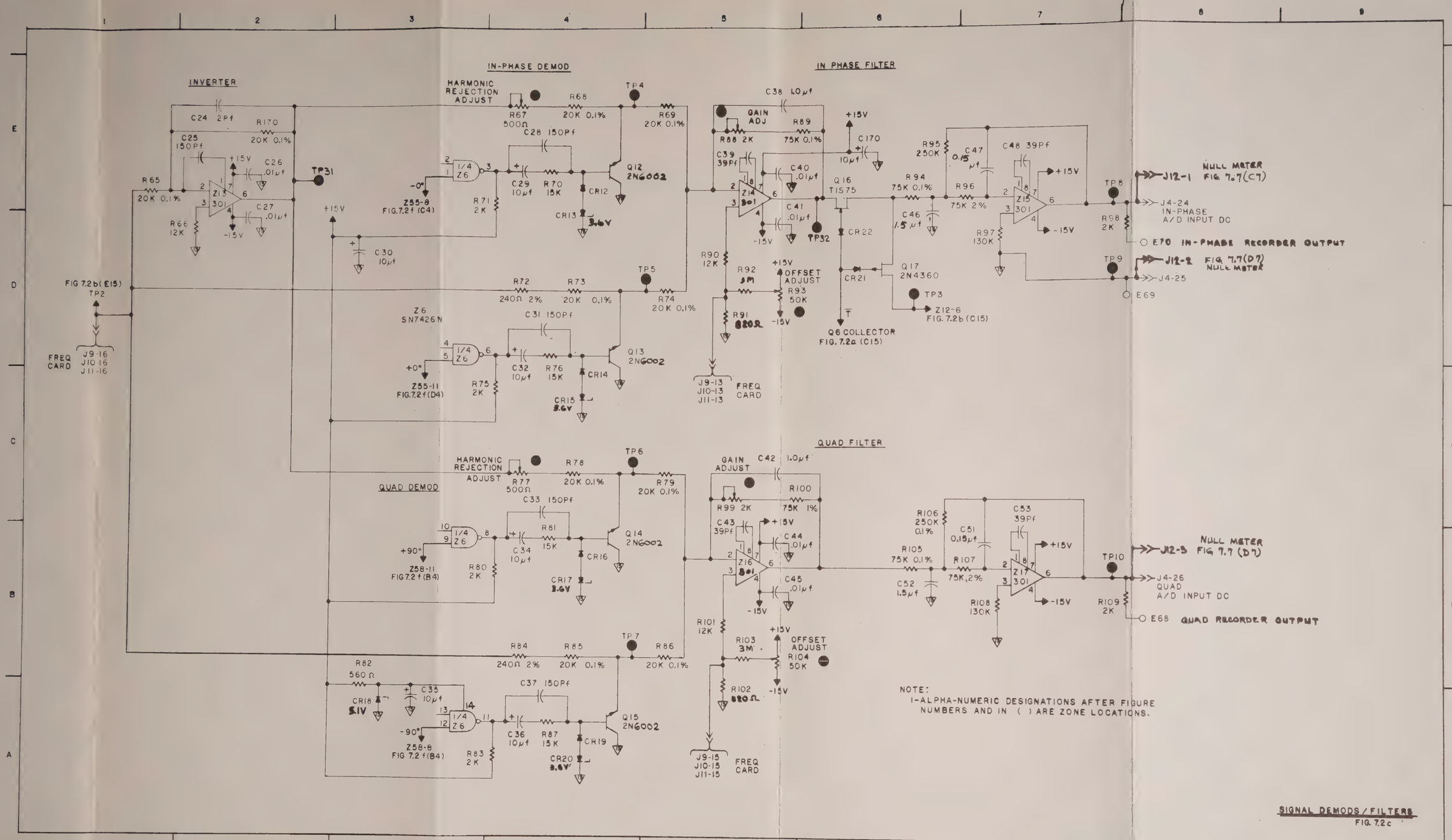
COMPONENT LOCATORS

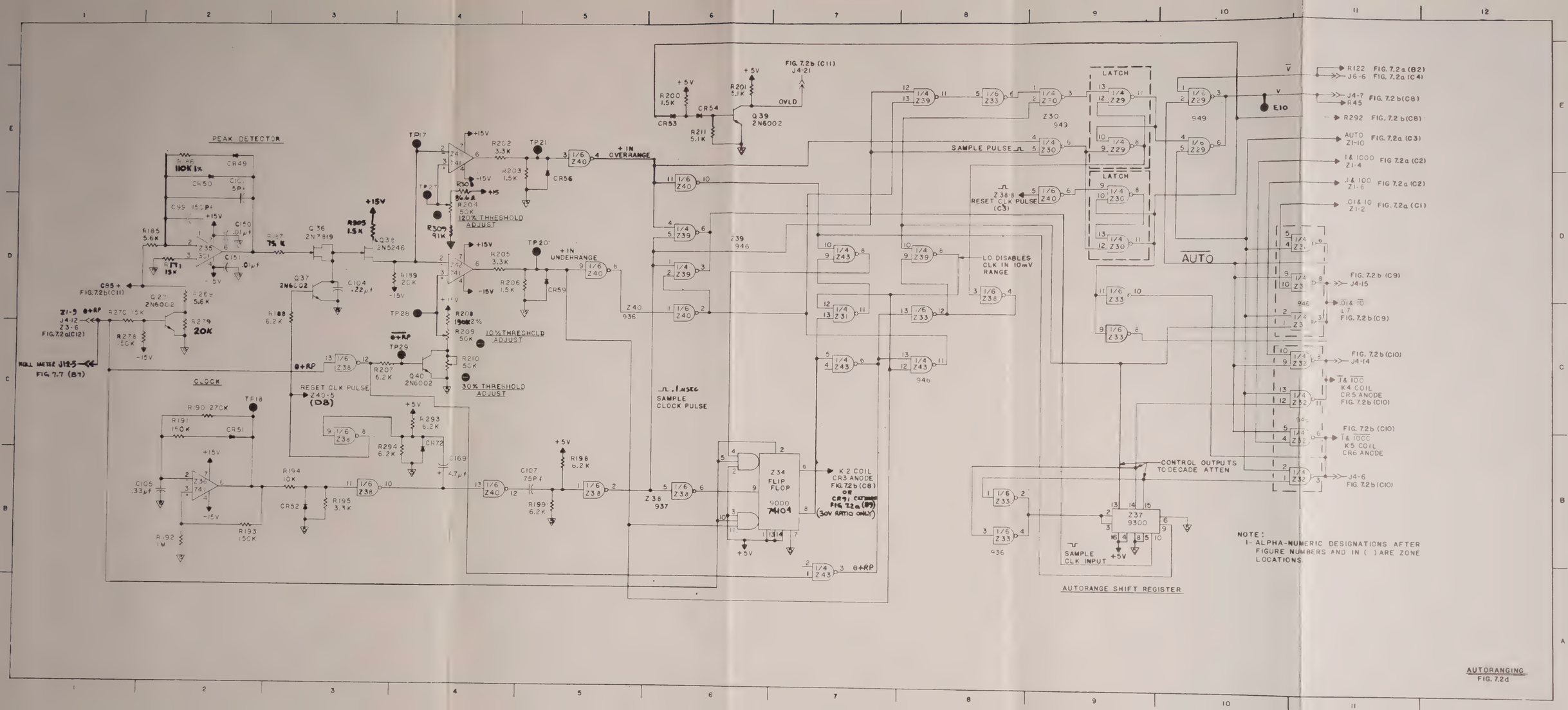


LOCATOR
MAIN BOARD SCHEMATIC
FIG. 7.1

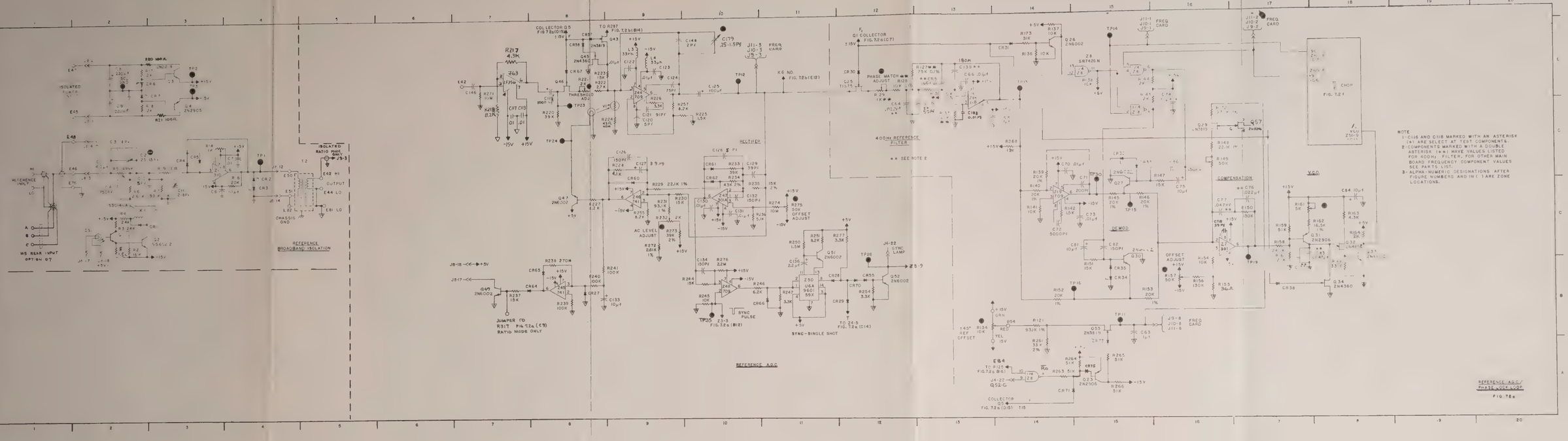

NOTE:
1- 10Ω RESISTORS MARKED WITH AN ASTERISK(*) ARE DELETED FOR REMOTE CONTROL OPTION.
2- DESIGNATION FOR THE CONTROL SIGNALS ARE 0 & +5V POSITIVE LOGIC. eg. "0" IS 0V. WHEN A VOLT RANGE IS SELECTED ; OR "0" SIGNAL IS +5V WHEN IN PHASE ANGLE MODE IS SELECTED. SIGNALS DESIGNATED ±15 ARE -15V IN LOGIC "0" AND +15V IN LOGIC "1".
3- ALPHA NUMERIC DESIGNATIONS AFTER FIGURE NUMBER AND IN ( ) ARE ZONE LOCATIONS.
4- ALL PUSH BUTTON SWITCHES WITH THE SAME REFERENCE DESIGNATION PREFIX, i.e. S3 A, S3 B, ARE MECHANICALLY INTERLOCKED AND ARE SHOWN IN THE NORMALLY OUT POSITION.
5- WHEN RATIO MODE OPTION IS SELECTED CR 41, 42 OR 43 MAY BE DELETED AND R9, R37, R38, CR38 THRU 41 MAY BE ADDED
AUTORANGING
FIG. 7.2d
FIGURE 7.6
REMOTE RANGE INPUTS
FIGURE 7.6
REMOTE FREQ.
SELECT INPUTS
REMOTE
CONTROL
ENABLE
FIG. 7.6
(E4)
CR 10,31,36,38
R301
FREQUENCY ENABLE SIGNAL
FIGURE 7.5
REMOTE FUNCTION INPUTS
FIG. 7.6
MODE ENABLE SIGNALS
REF. A.G.C.
FIG. 7.2e
FIG. 7.2e(A14)
CR71 ANODE
JUMPER FOR
LOCAL ONLY
THIS CONJUNCTION
FOR OP-03 ONLY
MANUAL RANGE SWITCHES
S1
(INTERLOCKING MECHANISM)
MANUAL FREQUENCY SWITCHES
S6
(INTERLOCKING MECHANISM)
MANUAL FUNCTION SWITCHES
S3
(INTERLOCKING MECHANISM)
CONTROL SWITCHES
FIG. 7.2a
IEEE BUSS ONLY
IEEE
VAR SCALE
LAND CUT WIRES CR91 IS USED
LOCAL
REMOTE
IN
OUT
S2

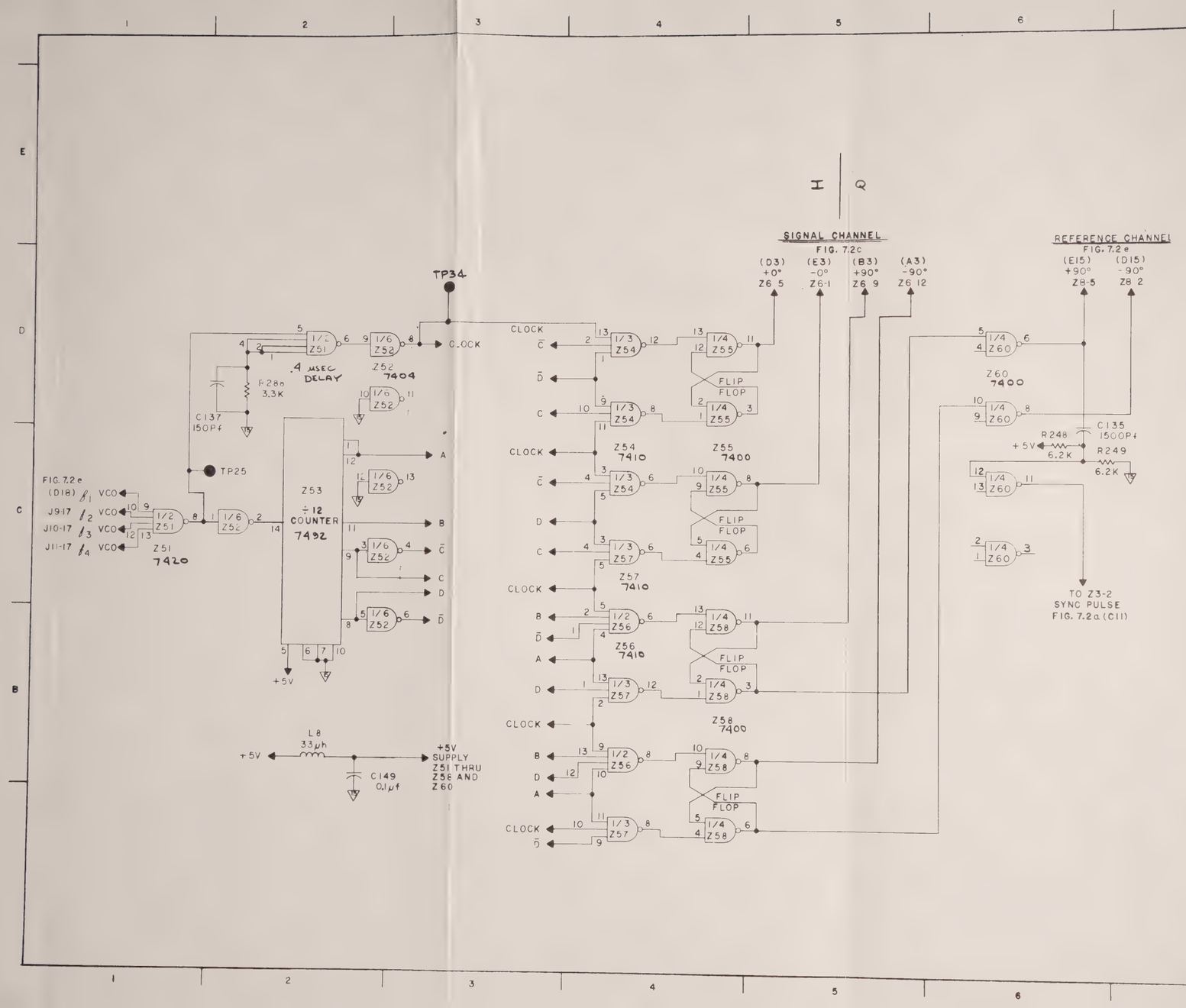

THESE COMPONENTS MUST BE OMITTED WHEN BROADBAND ISOLATION IS SUPPLIED
TO SIGNAL BROADBAND ISOLATION
TO SIGNAL DIRECT MODE MODULE OUTPUT
ISOLATED POWER INPUT
SOL GND
CHASSIS GND
REAR PANEL LINK
SIGNAL INPUT
MS REAR INPUT OPTION 07
SIGNAL BROADBAND ISOLATION MODULE
SIGNAL TRANSFORMER ISOLATION MODULE
SIGNAL DIRECT MODE MODULE
LOCATED ON MAIN BOARD
OUTPUT
AUTORANGING FIG. 7.2d
TO RANGE SWITCHES FIG. 7.2a
DECADE ATTEN
FREQ CARD
400Hz SIGNAL FILTER
SELECT AT TEST
GAIN ADJUST
OFFSET ADJUST
FUND
TOTAL MODE RECTIFIER
TOTAL MODE FILTER
SIGNAL FRONT END
FIG. 7.2b
NOTE:
1-C143 AND C144 MARKED WITH AN ASTERISK (*) ARE SELECT AT TEST COMPONENTS.
2-COMPONENTS MARKED WITH A DOUBLE ASTERISK (**) HAVE VALUES LISTED FOR 400Hz FILTER. FOR OTHER MAIN BOARD FREQUENCY COMPONENT VALUES SEE PARTS LIST.
3-ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBERS AND IN ( ) ARE ZONE LOCATIONS.

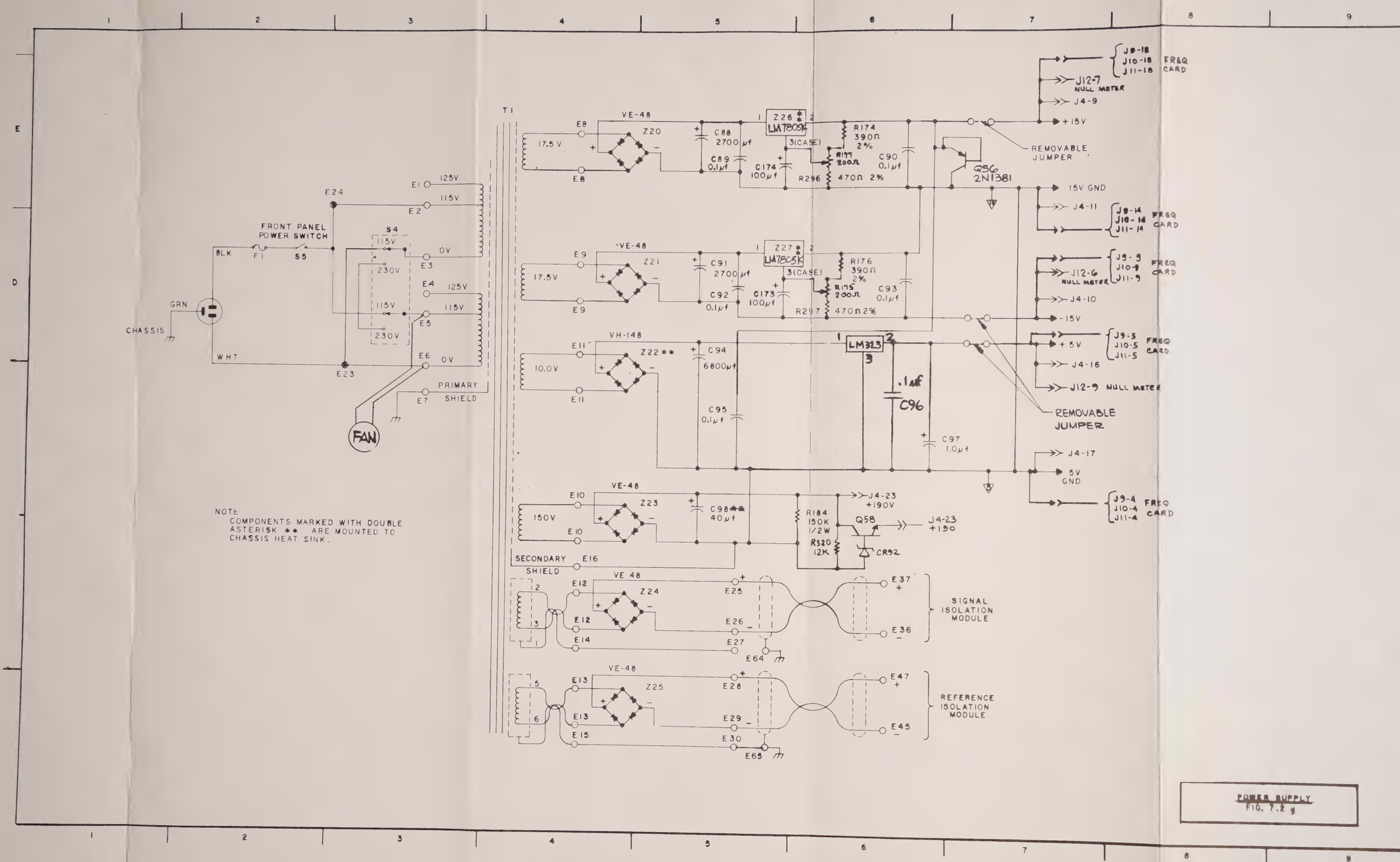

INVERTER
IN-PHASE DEMOD
IN PHASE FILTER
QUAD DEMOD
QUAD FILTER
HARMONIC REJECTION ADJUST
GAIN ADJ
OFFSET ADJUST
C24 2Pf
R170 20K 0.1%
C25 150Pf
C26 .01µf
C27 .01µf
R65 20K 0.1%
R66 12K
Z13 301
+15V
-15V
TP31
C30 10µf
R67 500Ω
R68 20K 0.1%
R69 20K 0.1%
TP4
C28 150Pf
C29 10µf
R70 15K
R71 2K
CR12
CR13 3.6V
Q12 2N6002
-0° Z55-8 FIG.7.2f (C4)
C38 1.0µf
R88 2K
R89 75K 0.1%
C170 10µf
C39 39Pf
C40 .01µf
C41 .01µf
Z14 301
Q16 TIS75
TP32
R90 12K
R92 3M
R93 50K
R91 820Ω
CR22
CR21
Q17 2N4360
TP3
Z12-6 FIG. 7.2b (C15)
Q6 COLLECTOR FIG. 7.2a (C15)
R94 75K 0.1%
C46 1.5µf
R95 250K
C47 0.15µf
R96 75K 2%
R97 130K
C48 39Pf
Z15 301
TP8
R98 2K
J12-1 NULL METER FIG 7.7(C7)
J4-24 IN-PHASE A/D INPUT DC
E70 IN-PHASE RECORDER OUTPUT
TP9
J12-2 FIG 7.7(D7) NULL METER
J4-25
E69
FIG 7.2b(E15) TP2
FREQ CARD J9-16 J10-16 J11-16
J9-13 J10-13 J11-13 FREQ CARD
Z6 SN7426N
R72 240Ω 2%
R73 20K 0.1%
R74 20K 0.1%
TP5
C31 150Pf
C32 10µf
R76 15K
R75 2K
CR14
CR15 3.6V
Q13 2N6002
+0° Z55-11 FIG.7.2f(D4)
HARMONIC REJECTION ADJUST
R77 500Ω
R78 20K 0.1%
R79 20K 0.1%
TP6
C33 150Pf
C34 10µf
R81 15K
R80 2K
CR16
CR17 3.6V
Q14 2N6002
+90° Z58-11 FIG 7.2f (B4)
GAIN ADJUST
C42 1.0µf
R99 2K
R100 75K 1%
C43 39Pf
C44 .01µf
C45 .01µf
Z16 301
R101 12K
R103 3M
R104 50K
R102 820Ω
J9-15 J10-15 J11-15 FREQ CARD
R106 250K 0.1%
R105 75K 0.1%
C52 1.5µf
C51 0.15µf
R107 75K,2%
R108 130K
C53 39Pf
Z17 301
TP10
R109 2K
J12-3 NULL METER FIG 7.7 (D7)
J4-26 QUAD A/D INPUT DC
E68 QUAD RECORDER OUTPUT
R84 240Ω 2%
R85 20K 0.1%
R86 20K 0.1%
TP7
R82 560Ω
CR18 5.1V
C35 10µf
C36 10µf
R87 15K
R83 2K
CR19
CR20 3.6V
C37 150Pf
Q15 2N6002
-90° Z58-8 FIG 7.2f (B4)
NOTE:
1-ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBERS AND IN ( ) ARE ZONE LOCATIONS.
SIGNAL DEMODS / FILTERS
FIG. 7.2c


PEAK DETECTOR
CLOCK
AUTORANGE SHIFT REGISTER
AUTO
LATCH
LATCH
+IN OVERRANGE
+IN UNDERRANGE
10% THRESHOLD ADJUST
30% THRESHOLD ADJUST
120% THRESHOLD ADJUST
OVLD
SAMPLE PULSE
RESET CLK PULSE (C3)
LO DISABLES CLK IN 10mV RANGE
SAMPLE CLOCK PULSE
CONTROL OUTPUTS TO DECADE ATTEN
SAMPLE CLK INPUT
K2 COIL CR3 ANODE FIG. 7.2b (C8) OR CR9 CATHODE FIG. 7.2a (B9) (30V RATIO ONLY)
FLIP FLOP
9000 7404
9300
R122 FIG. 7.2a (B2) J6-6 FIG. 7.2a (C4)
J4-7 FIG. 7.2b (C8) R45
R292 FIG. 7.2b (C8)
AUTO Z1-10 FIG. 7.2a (C3)
1& 1000 Z1-4 FIG 7.2a (C2)
1& 100 Z1-6 FIG 7.2a (C2)
.01& 10 Z1-2 FIG. 7.2a (C1)
FIG. 7.2b (C9) J4-15
.01& 10 L7 FIG. 7.2b (C9)
FIG. 7.2b (C10) J4-14
1& 100 K4 COIL CR5 ANODE FIG. 7.2b (C10)
FIG. 7.2b (C10) 1& 1000 K5 COIL CR6 ANODE
J4-6 FIG. 7.2b (C10)
NOTE: 1- ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBERS AND IN ( ) ARE ZONE LOCATIONS.

AUTORANGING
FIG. 7.2d

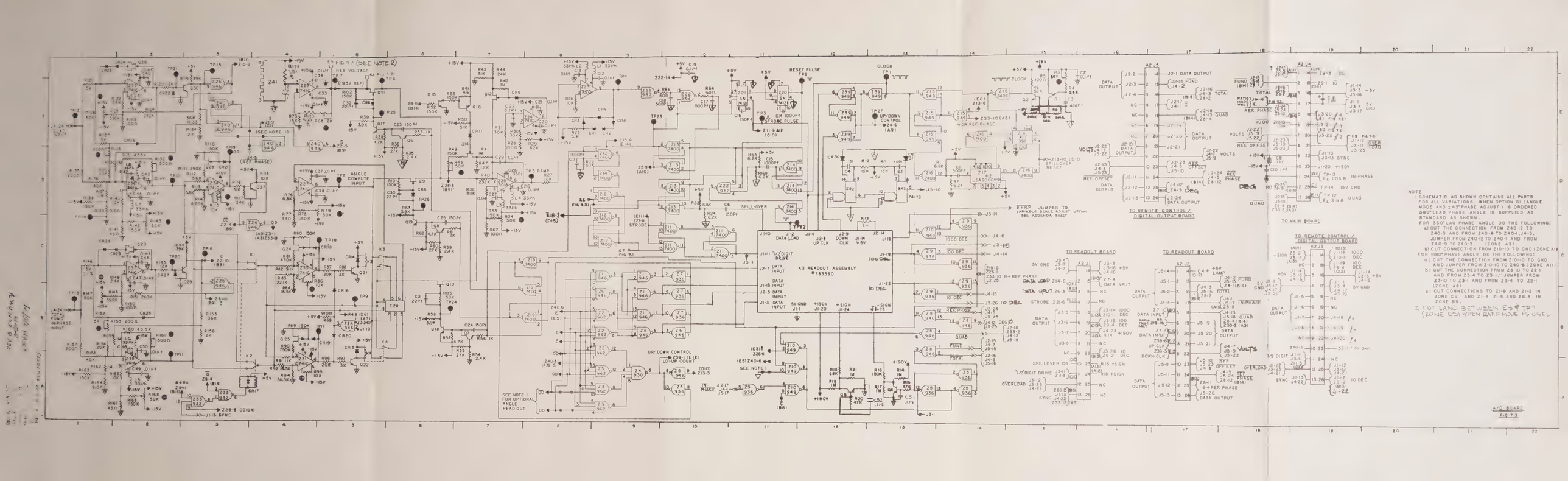

ISOLATED RATIO MODE SMA J5-3
OUTPUT
E42 HI
E44 LO
E81 LO
CHASSIS GND
REFERENCE BROADBAND ISOLATION
MS REAR INPUT OPTION 07
REFERENCE A2C
REFERENCE A2C/ PHASE LOCK NO2
FIG. 7.2a
NOTE
1- C116 AND C118 MARKED WITH AN ASTERISK (*) ARE SELECT AT TEST COMPONENTS.
2- COMPONENTS MARKED WITH A DOUBLE ASTERISK (**) HAVE VALUES LISTED FOR 400Hz FILTER. FOR OTHER MAIN BOARD FREQUENCY COMPONENT VALUES SEE PARTS LIST.
3- ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBERS AND IN ( ) ARE ZONE LOCATIONS.


I
Q
SIGNAL CHANNEL
FIG. 7.2c
REFERENCE CHANNEL
FIG. 7.2e
(D3) +0° Z6 5
(E3) -0° Z6-1
(B3) +90° Z6 9
(A3) -90° Z6 12
(E15) +90° Z8-5
(D15) -90° Z8 2
TP34
CLOCK
.4 MSEC DELAY
R286 3.3K
C137 150Pf
TP25
FIG. 7.2e
(D18) f1 VCO
J9-17 f2 VCO
J10-17 f3 VCO
J11-17 f4 VCO
Z51 7420
Z52 7404
Z53 ÷12 COUNTER 7492
Z54 7410
Z55 7400
Z56 7410
Z57 7410
Z58 7400
Z60 7400
FLIP FLOP
A
B
C
D
+5V
L8 33μh
C149 0.1μf
+5V SUPPLY Z51 THRU Z58 AND Z60
C135 1500Pf
R248 6.2K
R249 6.2K
TO Z3-2 SYNC PULSE FIG. 7.2a (C11)
NOTE:
1-ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBERS AND IN ( ) ARE ZONE LOCATIONS.
0 → TIME
+0° Z5 11
833μS
-0° Z5-9
1250μS
+90° Z8 11
625μS
-90° Z8-8
1875μS
Z3-3 SYNC PULSE
+4V
0V
TIMING SHOWN FOR 400Hz
π/6 WAVEFORMS
π/6 GENERATOR
FIG. 7.2 f

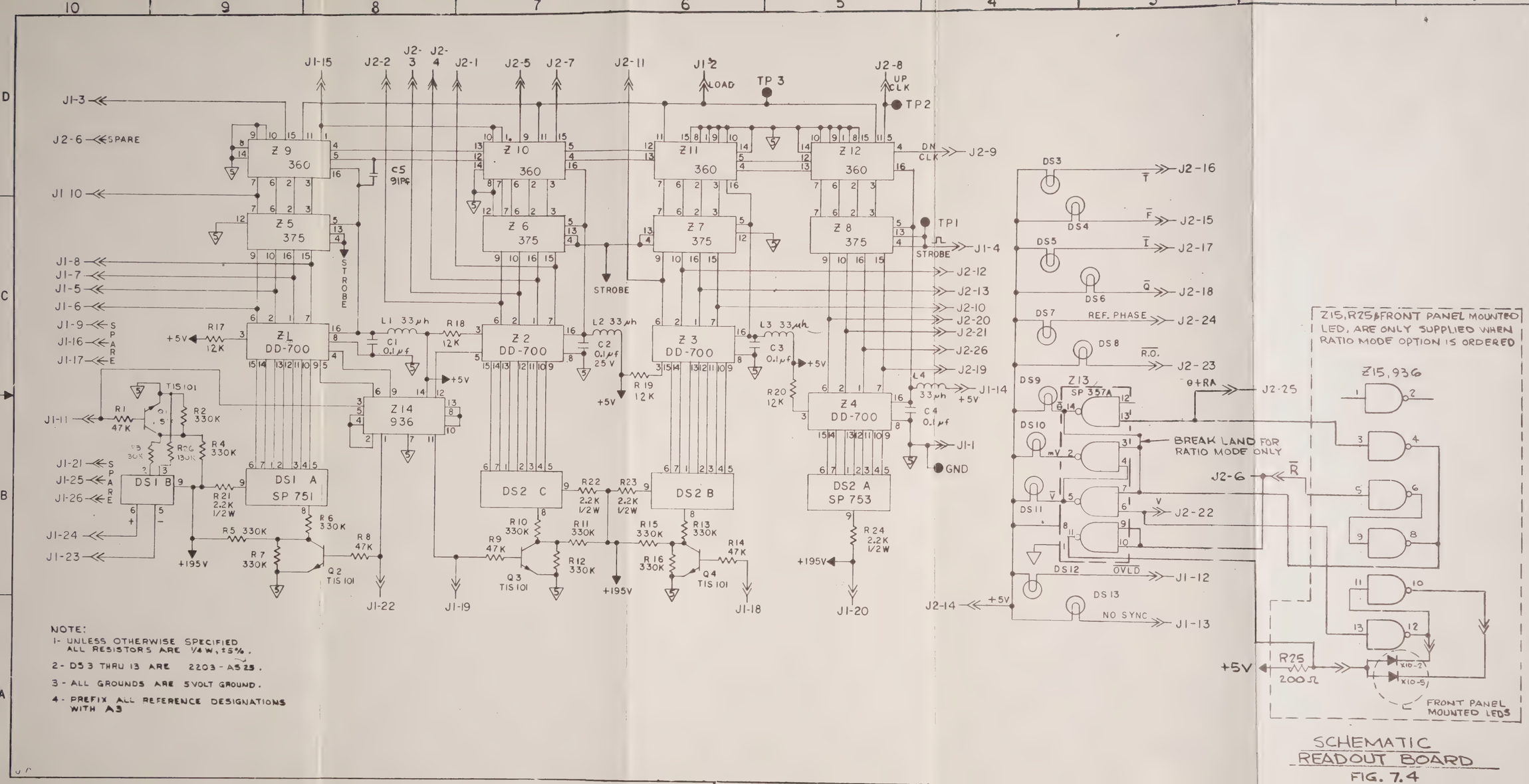


NOTE
COMPONENTS MARKED WITH DOUBLE ASTERISK ** ARE MOUNTED TO CHASSIS HEAT SINK.

POWER SUPPLY
FIG. 7.2 g

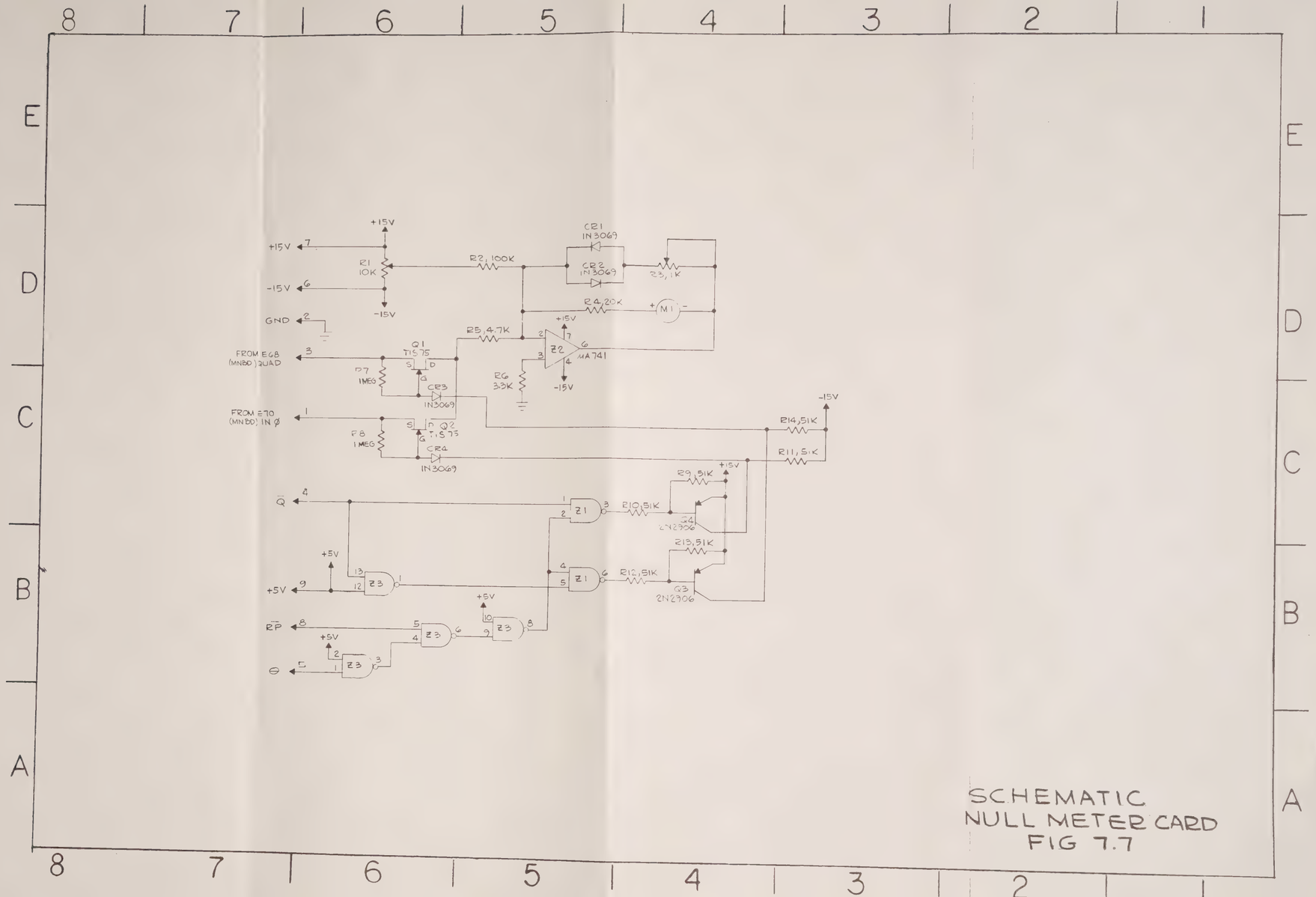


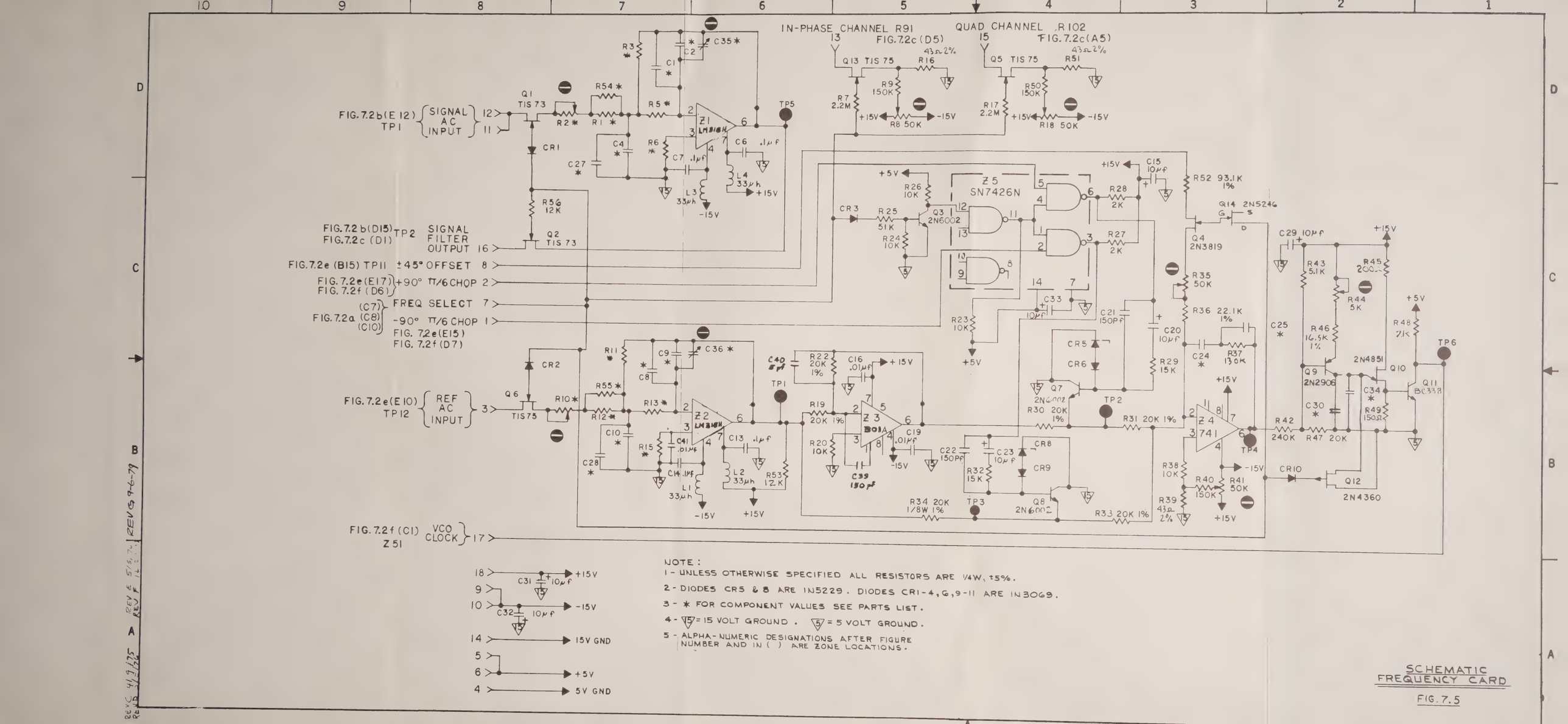
NOTE
1 SCHEMATIC AS SHOWN CONTAINS ALL PARTS FOR ALL VARIATIONS. WHEN OPTION D (ANGLE MODE AND ± 45° PHASE ADJUST) IS ORDERED 360° LEAD PHASE ANGLE IS SUPPLIED AS STANDARD AS SHOWN.
FOR 360° LAG PHASE ANGLE DO THE FOLLOWING:
a) CUT THE CONNECTION FROM Z40-12 TO Z40-3 AND FROM Z40-9 TO Z40-11, J4-5. JUMPER FROM Z40-12 TO Z40-11 AND FROM Z40-9 TO Z40-3. (ZONE A3).
b) CUT CONNECTION FROM Z10-10 TO GND (ZONE A11) FOR 180° PHASE ANGLE DO THE FOLLOWING:
a.) CUT THE CONNECTION FROM Z3-10 TO GND AND JUMPER FROM Z10-10 TO Z40-8 (ZONE A11)
b.) CUT THE CONNECTION FROM Z3-10 TO Z2-11 AND FROM Z3-4 TO Z3-11. JUMPER FROM Z3-10 TO Z3-11 AND FROM Z3-4 TO Z2-11 (ZONE A8)
c) CUT CONNECTIONS TO Z1-9 AND Z1-2 IN ZONE C9 AND Z1-4 Z1-5 AND Z6-4 IN ZONE B9.
2. CUT LAND BETWEEN E8 & TP7 (ZONE E5) WHEN RATIO MODE IS USED.

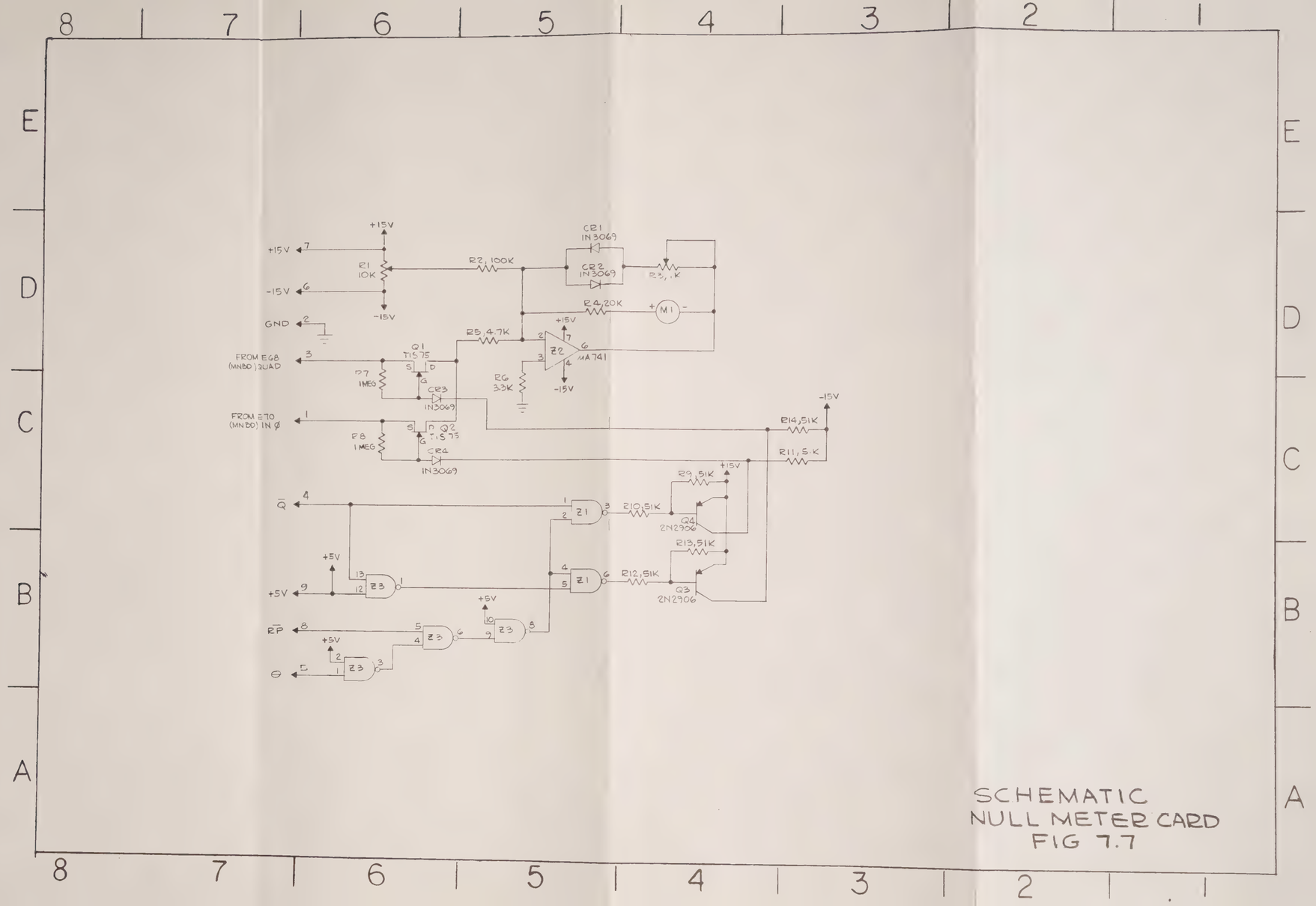


NOTE:
1- UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE 1/4W, ±5%.
2- D53 THRU 13 ARE 2203-A525.
3- ALL GROUNDS ARE 5VOLT GROUND.
4- PREFIX ALL REFERENCE DESIGNATIONS WITH A3

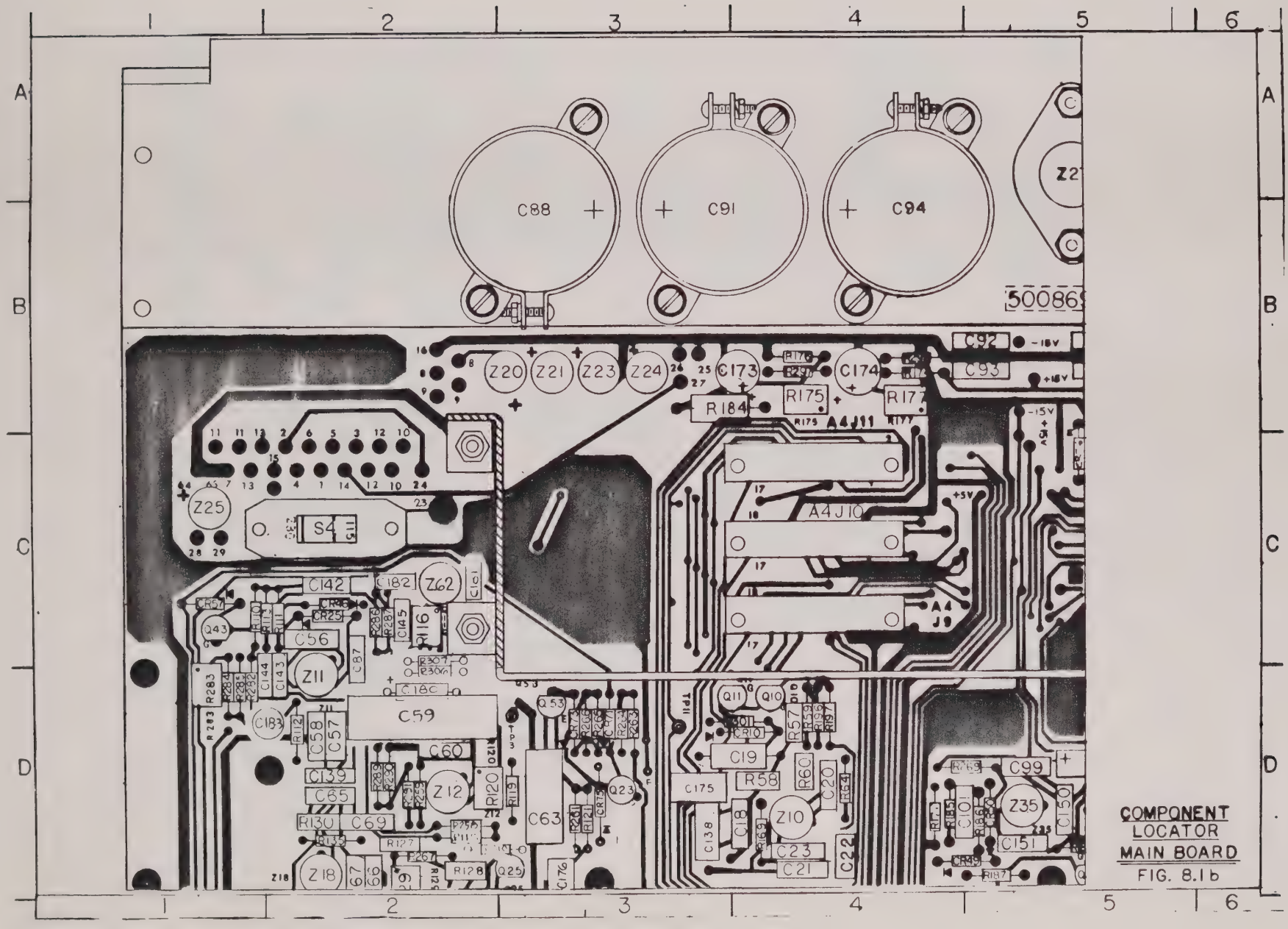
SCHEMATIC
READOUT BOARD
FIG. 7.4

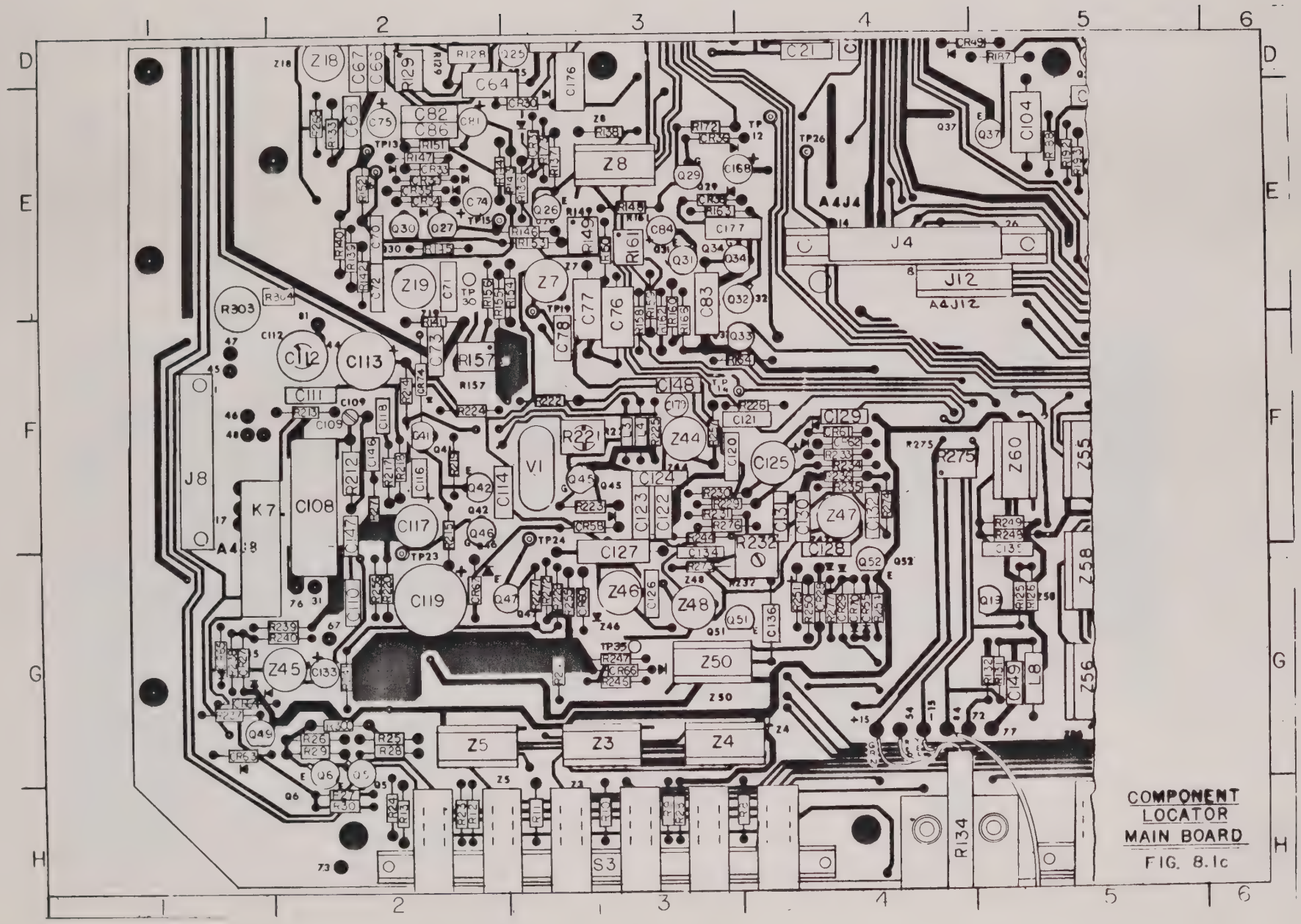

8
7
6
5
4
3
2
1
E
D
C
B
A
+15V
-15V
GND
R1 10K
R2, 100K
R3, 1K
R4, 20K
R5, 4.7K
R6 3.3K
R7 1MEG
R8 1MEG
R9, 51K
R10, 51K
R11, 51K
R12, 51K
R13, 51K
R14, 51K
CR1 IN3069
CR2 IN3069
CR3 IN3069
CR4 IN3069
Q1 TIS 75
Q2 TIS 75
Q3 2N2906
Q4 2N2906
Z1
Z2 MA741
Z3
M1
FROM E68 (MN80) QUAD
FROM E70 (MN80) IN Ø
Q
Ø
RP
SCHEMATIC
NULL METER CARD
FIG 7.7

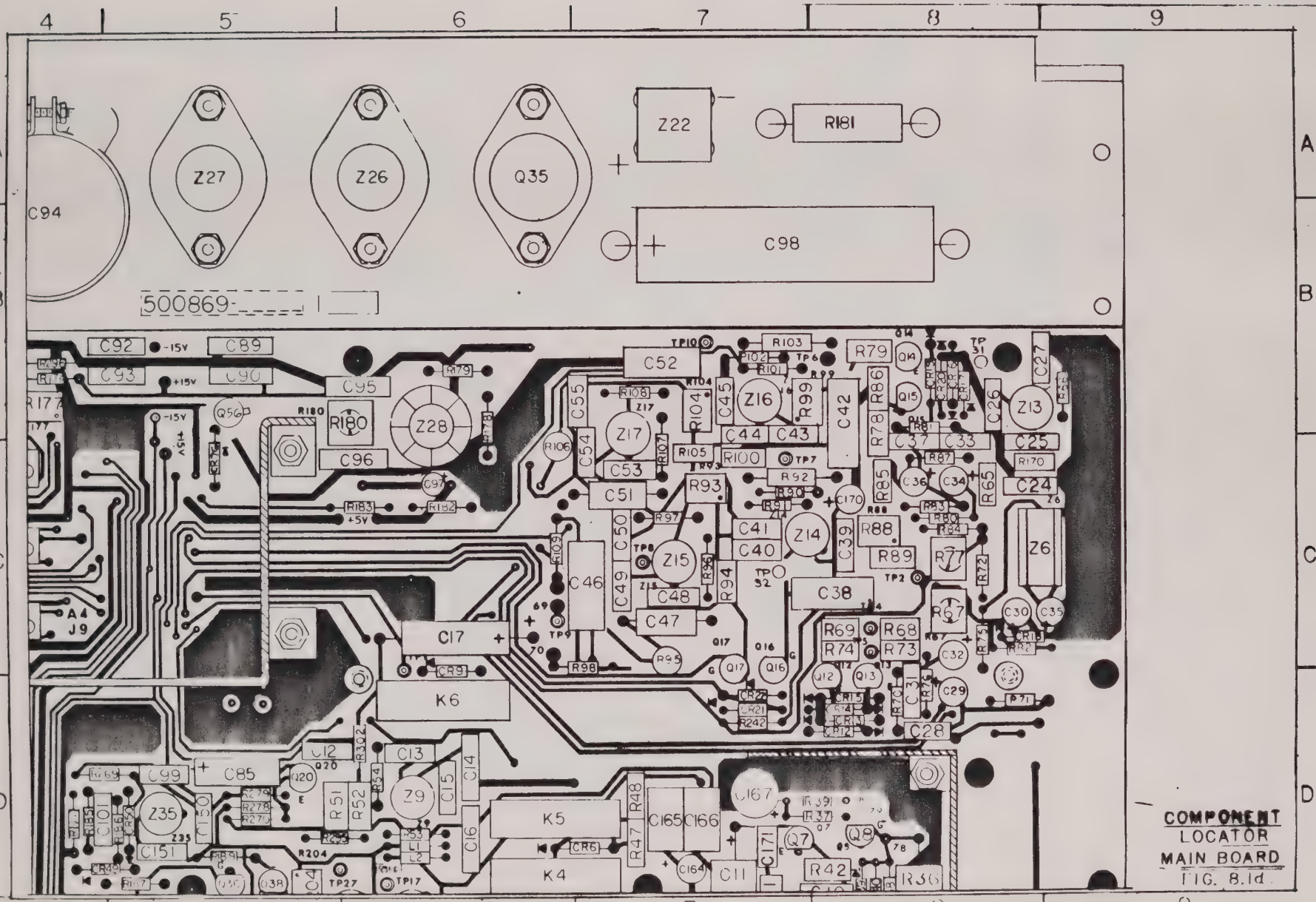

IN-PHASE CHANNEL R91 FIG. 7.2c (D5)
QUAD CHANNEL R102 FIG. 7.2c (A5)
FIG. 7.2b (E12) TP1 SIGNAL AC INPUT
FIG. 7.2b (D15) FIG. 7.2c (D1) TP2 SIGNAL FILTER OUTPUT
FIG. 7.2e (B15) TP11 ±45° OFFSET
FIG. 7.2e (E17) FIG. 7.2f (D6) +90° π/6 CHOP
FIG. 7.2a (C7) (C8) (C10) FREQ SELECT
-90° π/6 CHOP
FIG. 7.2e (E15) FIG. 7.2f (D7)
FIG. 7.2e (E10) TP12 REF AC INPUT
FIG. 7.2f (C1) Z51 VCO CLOCK
Z1 LM318H
Z2 LM318H
Z3 301A
Z4 741
Z5 SN7426N
Q1 TIS 73
Q2 TIS 73
Q3 2N6002
Q4 2N3819
Q5 TIS 75
Q6 TIS75
Q7 2N6002
Q8 2N6002
Q9 2N2906
Q10 2N4851
Q11 BC338
Q12 2N4360
Q13 TIS 75
Q14 2N5246
TP1
TP2
TP3
TP4
TP5
TP6
+15V
-15V
+5V
NOTE:
1 - UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE 1/4W, ±5%.
2 - DIODES CR5 & 8 ARE IN5229. DIODES CR1-4, 6, 9-11 ARE IN3069.
3 - * FOR COMPONENT VALUES SEE PARTS LIST.
4 - 15 = 15 VOLT GROUND. 5 = 5 VOLT GROUND.
5 - ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBER AND IN ( ) ARE ZONE LOCATIONS.
SCHEMATIC
FREQUENCY CARD
FIG. 7.5

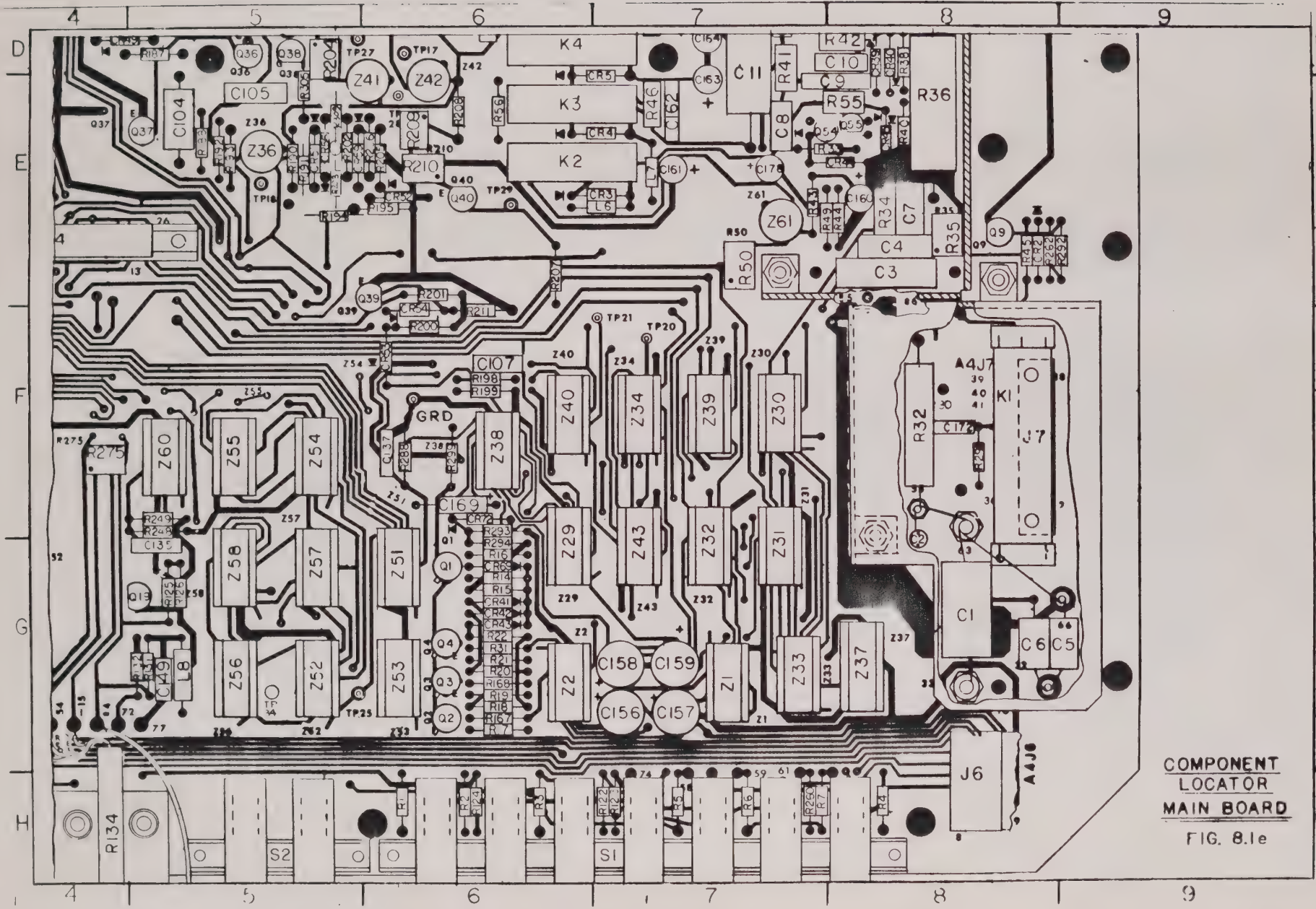


SCHEMATIC
NULL METER CARD
FIG 7.7


C88
C91
C94
Z2
500865
Z20
Z21
Z23
Z24
C173
C174
C92
C93
-18V
+18V
R184
R175
R177
-15V
+5V
A4J11
A4J10
A4J9
Z25
S4
C142
C182
Z62
C181
CR24
CR25
Q24
C56
C145
R116
C87
Z11
C144
C143
C180
C59
C183
C58
C57
C60
C139
C65
R130
C69
R127
Z18
R128
Q25
C63
Z12
R120
R113
Q23
C176
Q53
Q11
Q10
CR10
R57
C19
R58
R60
C20
C175
C18
C138
Z10
C23
C21
C22
C99
Z35
C150
C151
CR49
R187
COMPONENT
LOCATOR
MAIN BOARD
FIG. 8.1b


COMPONENT
LOCATOR
MAIN BOARD
FIG. 8.1c


4
5
6
7
8
9
A
B
C
D
Z27
Z26
Q35
Z22
R181
C94
C98
500869
C92
C89
C93
C90
C95
R180
Z28
C96
C52
C55
C54
C53
C51
C50
C49
C46
C48
C47
C45
C44
C43
C42
C41
C40
C39
C38
Z16
Z17
Z15
Z14
R103
R104
R105
R100
R93
R92
R90
R99
R97
R94
R95
R98
R79
R78
R86
R85
R88
R89
R77
R69
R68
R74
R73
R67
R72
R65
C37
C33
C36
C34
C27
C26
C25
C24
Z13
Z6
C30
C35
C32
C29
C28
C31
C17
K6
K5
K4
C12
C13
C14
C15
C16
C85
C99
C101
C151
Z35
Z9
R51
R52
R54
R48
R47
C165
C166
C167
C164
C11
C171
Q7
Q8
R42
R36
R37
C10
TP27
TP17
A4
J9
-15V
+15V
+5V
COMPONENT
LOCATOR
MAIN BOARD
FIG. 8.1d


COMPONENT
LOCATOR
MAIN BOARD
FIG. 8.1e

	R	C	CR	Q	Z	L	J	K	TP
1	C4	C4	E4	B3	A4	F4	C8	D13	C3
2	C4	C3	E4	C4	A2	F4	C6	D12	E4
3	B3	B4	E4	C4	B2	F10	C8	F13	E4
4	B4	B4	E4	D9	B2	E10	C7	F14	E3
5	B3	C4	E4	D9	D8	C12	C6		E9
6	C4	B9	F10	F2	A3	C12			F11
7		B6		F3	A5	B14			E12
8	C3	C7	F11	F1	D7	B14			E12
9	C4	B3	F10	F11	D9				F15
10	B4	B2		F11	D5				B14
11	B4	F4	E11	F11	B8				B13
12	C4	F3	E13	F10	B6				A13
13	B4	F3	F13		E5				B12
14	D9	E4	E15	E11	E9				A12
15	C9	D4	E15	E11	B5				C10
16	C9	E2	B15	E11	C5				C10
17	D9	D3	D12	F2	B5				D14
18	C9	E2	D13	F3	C5				D14
19	D9	D3	D14	F2	C2				D11
20	C9	F8	B15	F13	D4				C11
21	D9	F8	D11	E15	D2				B11
22	B6	F9	A10	E15	D3				E9
23	E5	E2	A13	B11	F4				D5
24	E5	E2	B13	D14	F8				F3
25	E3	E1	B11	D14	E10				F2
26	E4	E10	B13	B13	B9				F2
27	F5	E10	B10	C11	E13				D2
28	F7	E10	A12	D12	F14				
29	F7	E10	B11	C10	F12				
30	F7	F11		B10	D14				
31	F9	E11			D15				GND
32	D10	E11							TPS
33	D10	E12			B10				F9
34	D10	E12			C11				B3
35	E2				A13				D2
36	E2				B14				
37	E2	E12			B11				CLK
38	E2	F12			D13				C3
39	E2				C3				
40	E10	B12			A9				

	R	C	TP
41	E10	B12	+15V
42	F10	B14	C3
43	F10	B14	
44	F10	A14	-15V
45			B2
46		B11	
47	E11	B11	
48	F11	D13	
49	E11	C12	
50	E11	D12	
51	E12		
52	D9		
53	E12		
54	E3		
55	E3		
56	E3		
57	E3		
58	E3		
59	E1		
60	E1		
61	E1		
62	E2		
63	E2		
64	D3		
65	D2		
66	E3		
67	D10		
68	F12		
69	B10		
70			
71	F13		
72	F13		
73	F12		
74			
75			
76	E13		
77	E13		
78	E13		
79	E14		
80	C14		

	R
81	C14
82	C14
83	C14
84	C14
85	F11
86	D14
87	D14
88	E15
89	C14
90	C15
91	C15
92	C15
93	
94	C15
95	D15
96	D14
97	D15
98	
99	
100	
101	F11
102	F11
103	
104	
105	
106	
107	
108	
109	
110	D11
111	C12
112	C12
113	C12
114	C12
115	D11
116	C11
117	C11
118	C10
119	B10
120	B10

	R
121	B13
122	A13
123	A12
124	B12
125	A12
126	A12
127	A13
128	B13
129	B14
130	A14
131	B15
132	B14
133	C11
134	B11
135	A14
136	A15
137	A14
138	A14
139	A14
140	A14
141	A14
142	A14
143	B14
144	C10
145	B11
146	B12
147	B11
148	A11
149	A11
150	A11
151	B11
152	B12
153	B12
154	C13
155	C11
156	C11
157	B12
158	C13
159	C13
160	C13

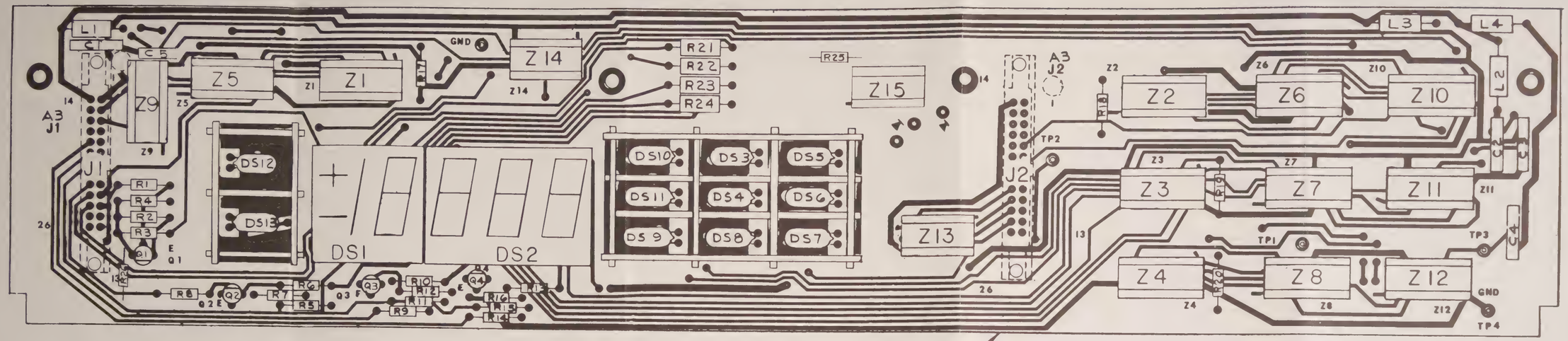
	R
161	C13
162	C13
163	C14
164	C13
165	C13
166	C12
167	C12
168	D12
169	D2
170	**F11

*CR8 REQUIRED FOR STANDARD UNITS

**R170 REPLACES CR8 IN RATIO UNITS

COMPONENT LOCATOR - A/D BOARD
FIGURE 8.2a

TO LOCATE A COMPONENT ON THE COMPONENT LOCATOR, FIND ZONE USING ABOVE TABLE (ZONE FOR R1 IS C4, ZONE FOR C5 IS C4). COMPONENT CAN THEN BE LOCATED WITHIN THE ZONE INDICATED.



COMPONENT LOCATIONS

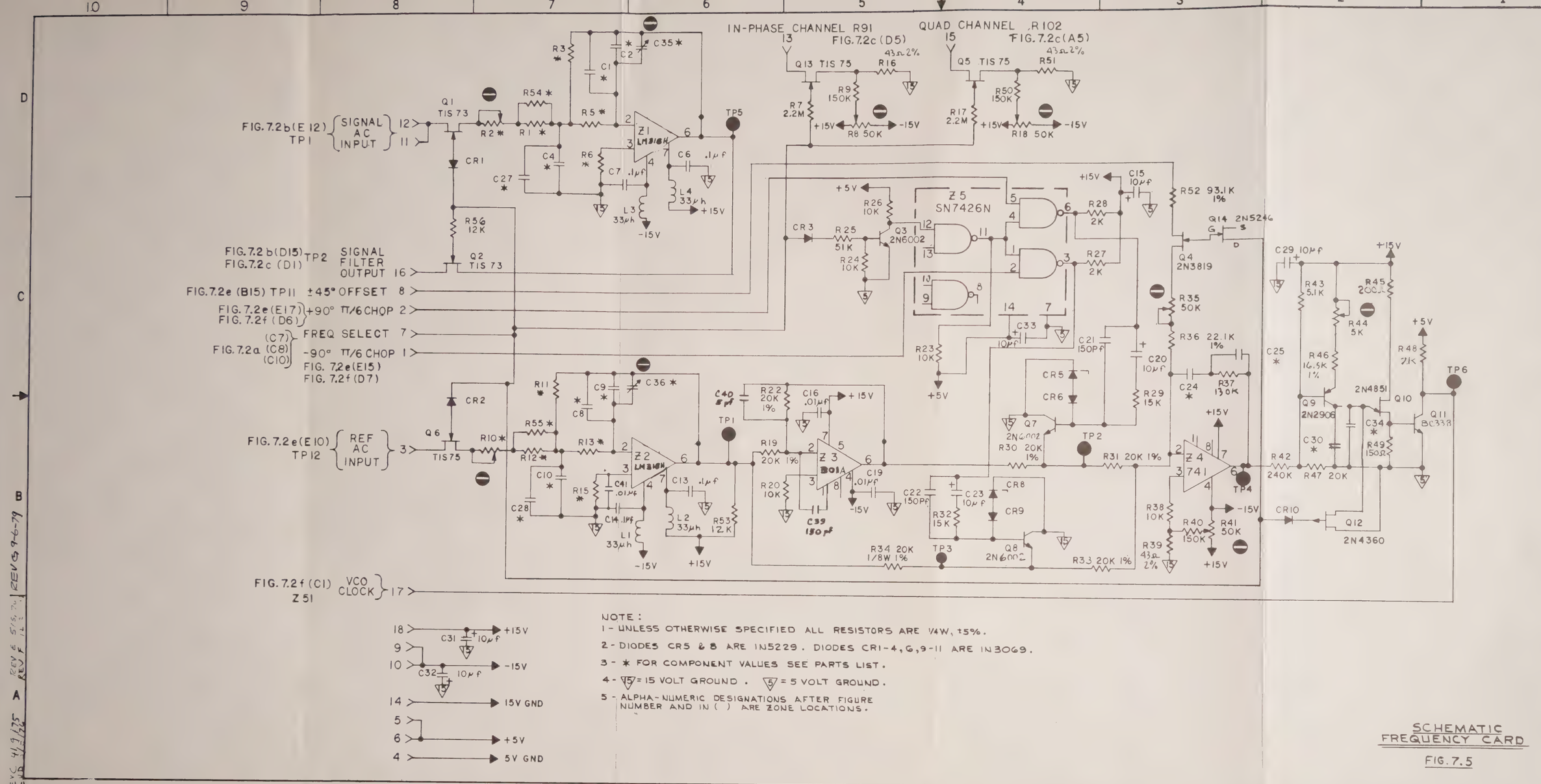
	R	C	Q	Z	DS	J	TP	L
1	D10	E10	D10	E8	D8	D10	D2	E10
2	D10	D1	C9	E3	D7	D4	D4	E1
3	D10	D1	C8	D3	D6		D1	E2
4	D10	D1	C8	D3	D6		C1	E1
5	C9	E10		E9	D5			
6	D9			E2	D5			
7	C9			D2	D5			
8	C10			D2	D6			
9	C8			E10	D7			
10	D8			E1	D7		GND TP	
11	C8			D1	D7			
12	D8			D1	D9		E8	

	R	Z	DS	
13	D7	D5	D9	
14	C7	E7		
15	C7	E5		
16	C7			
17	E8			
18	E4			
19	D3			
20	D3			
21	E6			
22	E6			
23	E6			
24	E6			

	R
25	E5
26	D10
27	
28	

Z2,3,4,6,7,8,10,11&12 SHOWN IN APPROX POSITION. THESE COMPONENTS MAY BE SHIFTED SLIGHTLY TO ACCOMODATE CUTOUT IN BOARD FOR NULL METER MTG.

COMPONENT LOCATOR
READOUT BOARD
FIG. 8.3



NOTE:

1 - UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE 1/4W, ±5%.

2 - DIODES CR5 & 8 ARE IN5229. DIODES CR1-4, 6, 9-11 ARE IN3069.

3 - * FOR COMPONENT VALUES SEE PARTS LIST.

4 - (15) = 15 VOLT GROUND . (5) = 5 VOLT GROUND.

5 - ALPHA-NUMERIC DESIGNATIONS AFTER FIGURE NUMBER AND IN ( ) ARE ZONE LOCATIONS.

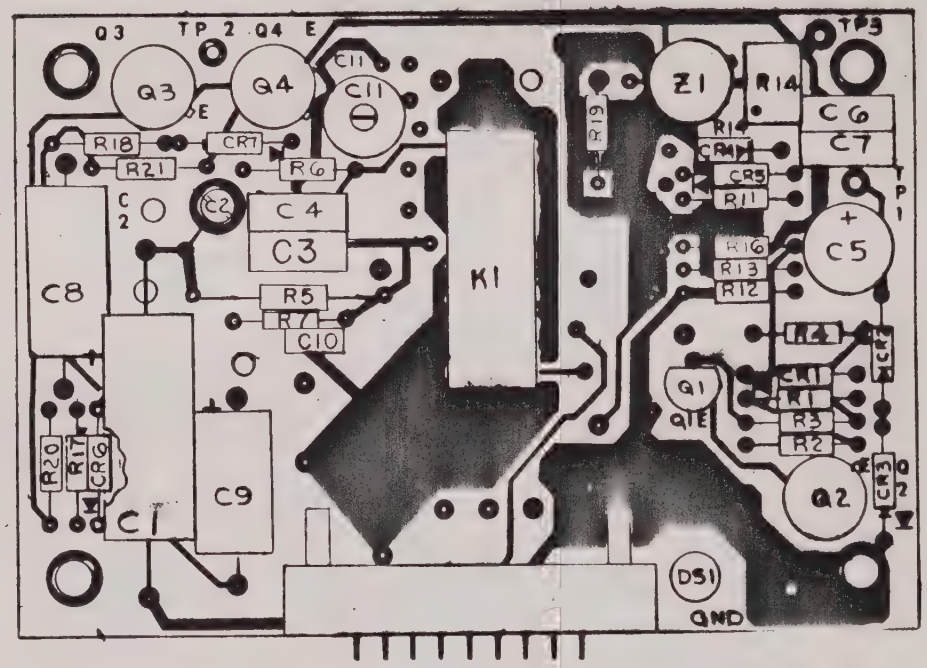
REV C 4/3/75 REV E 5/15/79 REV F 7/3/79 REV G 9-6-79

SCHEMATIC
FREQUENCY CARD

FIG. 7.5

COMPONENT LOCATIONS

	R	C	CR	Q	Z	DS	TP	K
1	C1	C4	C1	C2	E2	B2	D1	D3
2	C1	D4	C1	C1			E4	
3	C1	D4	C1	E4			E1	
4	D1	D4	D2	E4				
5	D4	D1	D2					
6	D3	E1	C4					
7	D4	D1	D4					
8		D5						
9		C4						
10		D3						
11	D2	E3	-					
12	D2							
13	D2							
14	E1							
15								
16	D2							
17	C5							
18	D4							
19	D2							
20	C5							
21	D4							
GND							B1	



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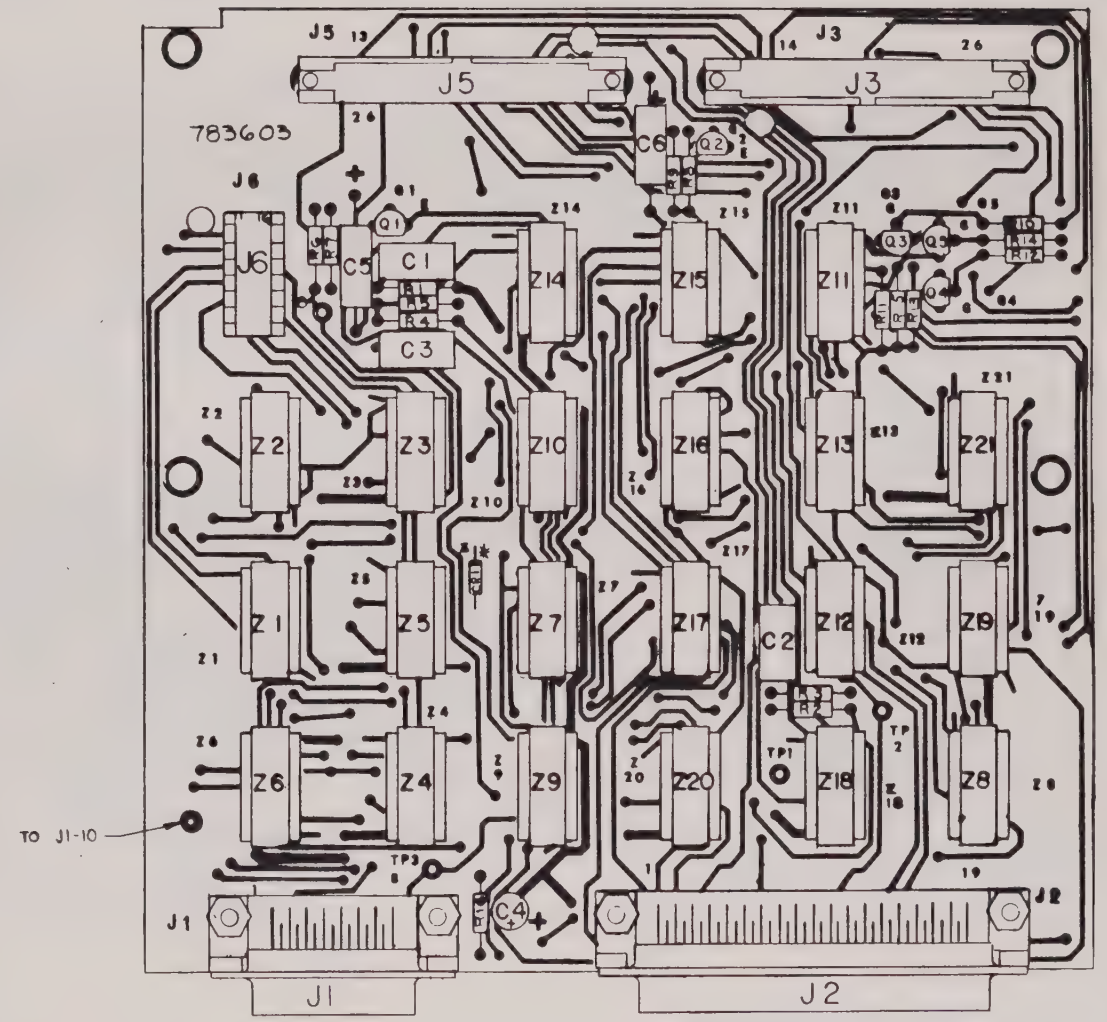
COMPONENT LOCATOR
REFERENCE ISOLATION BOARD

FIG. 8.5

COMPONENT LOCATIONS

	R	C	Q	Z	J	TP	E
1	D4	D4	E4	C5	A4	B2	
2	B2	C2	E3	D5	A2	B2	
3	B2	D4	D2	D4	E2	B4	
4	D4	A3	D2	B4			
5	D4	D4	D2	C4	E4		
6	D4	E3		B5	D5		
7	D4			C3			
8	E3			B1			
9	E3			B3			
10	E1			D3			
11	D2			D2			
12	D1			C2			
13	D2			D2			
14	D1			D3			
15	D2			D3			
16	A4			D3			
17				C3			
18				B2			
19				C1			
20				B3			
21				D1			
84							D4

* CR1 ZONE C4 FOR RATIO MODE (-1) UNIT ONLY



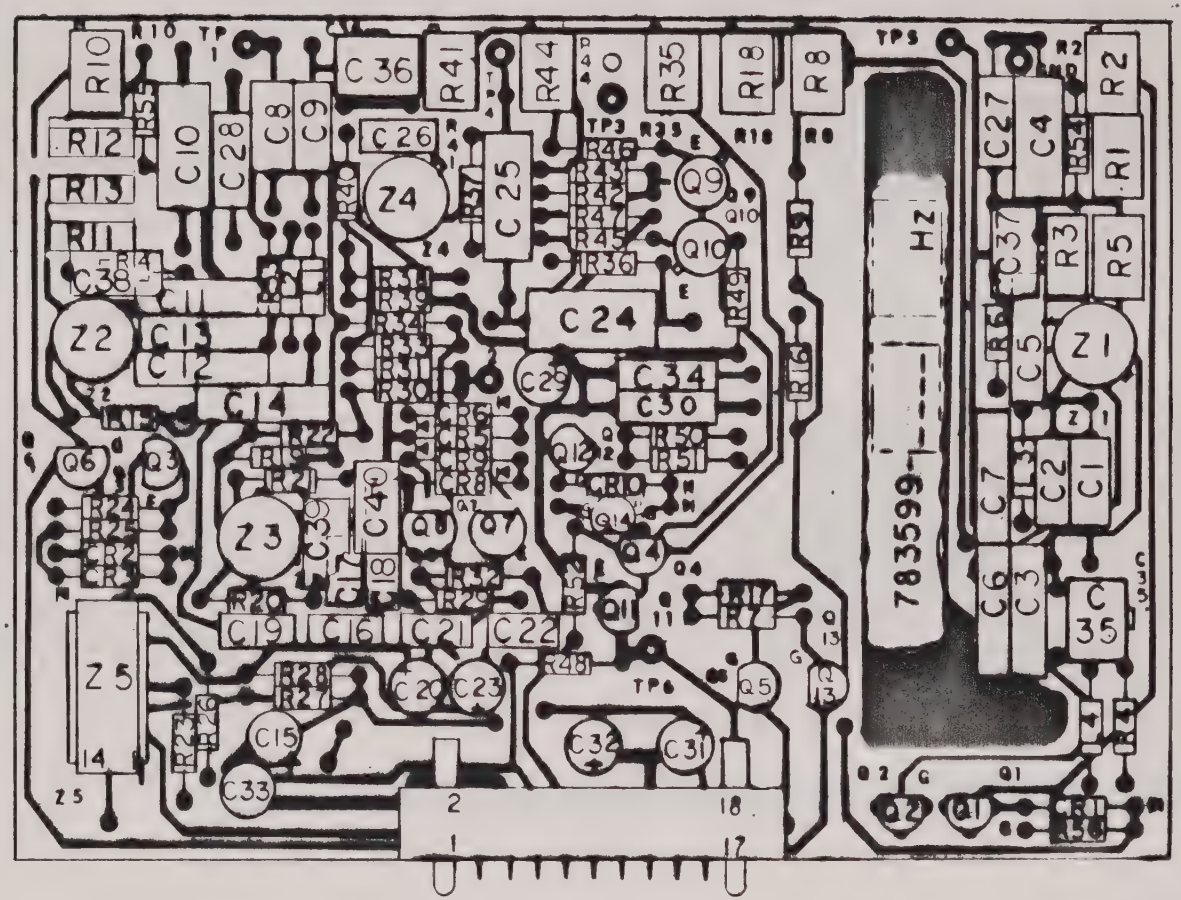
COMPONENT LOCATOR
REMOTE CONTROL/DIGITAL OUTPUT BOARD
FIG 86

COMPONENT LOCATIONS

	R	C	CR	Q	Z
1	E1	C1	B1	B2	D1
2	E1	C1	C5	B2	D6
3	D1	C1	C5	C5	C5
4	B1	E1		C3	D4
5	D1	D1	C4	B3	B5
6	D1	C2	C4	C6	
7	C3	C2		C4	
8	E2	E5	C4	C4	
9	D2	E5	C4	D3	
10	E6	E5	C3	D3	
11	D6	D5		C3	
12	E6	D5		C3	
13	D6	D5		B2	
14	D5	C5		C3	
15	C5	B5			
16	D2	B4			
17	C3	C4			
18	E3	C4			
19	C5	B5			
20	C5	B4			
21	C5	B4			
22	C5	B4			
23	B5	B4			
24	C5	D3			
25	C5	D4			
26	B5	E4			
27	B5	E1			
28	B5	E5			
29	C4	D3			
30	D4	C3			
31	D4	B3			
32	C4	B3			
33	D4	B5			
34	D4	D3			
35	E3	B1			
36	D3	E4			
37	D4	D1			

	R	C
38	D4	D5
39	D4	C4
40	D4	C4
41	E4	
42	D3	
43	E3	
44	E3	
45	D3	
46	E3	
47	D3	
48	B3	
49	D3	
50	C3	
51	C3	
52	C3	
53	D5	
54	E1	
55	E5	
56	B1	1
57		
58		
59		

	L	TP
1	D5	E5
2	D5	D4
3	C1	E3
4	B1	E4
5		E2
6		B3
GND		E1

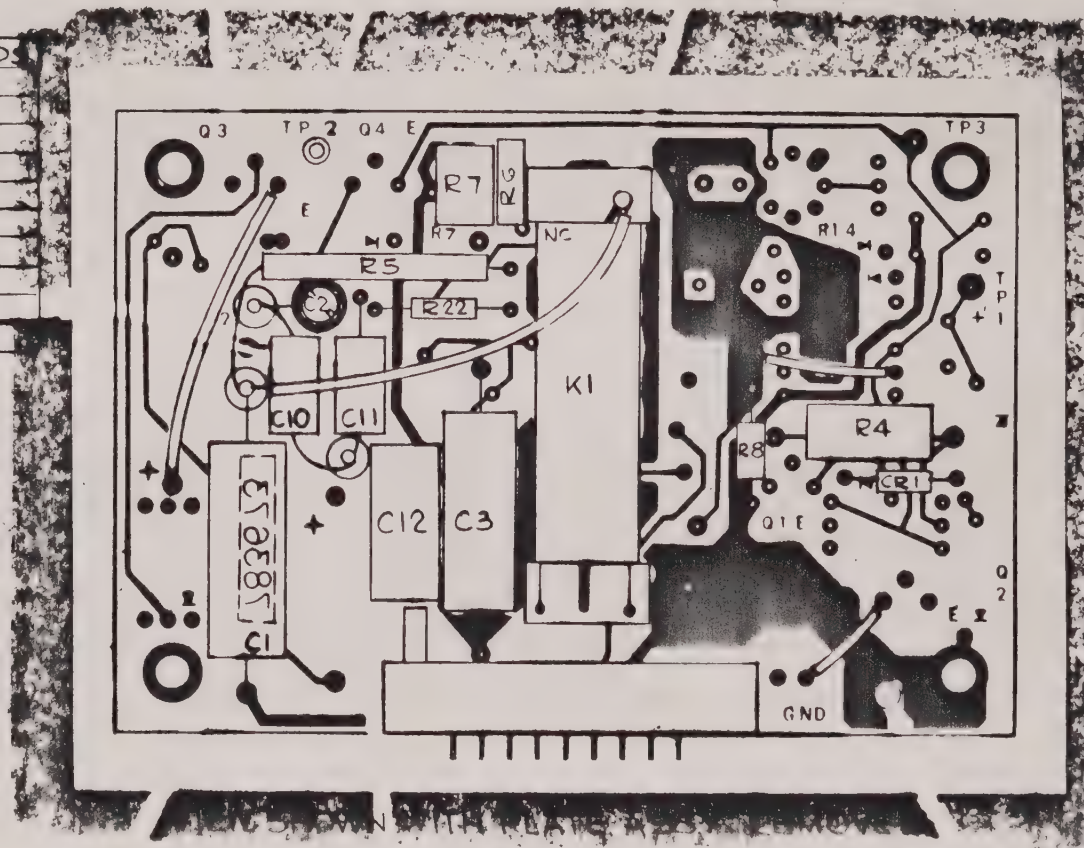


COMPONENT LOCATOR FREQUENCY CARD

FIG. 8.7

COMPONENT LOCATIONS

	R	C	CR	Q	E	TP	L	K	D
1	C1	C4	C1					D3	
2		D4				E4			
3		C3							
4	D1								
5	D4								
6	E3								
7	E3								
8	D2								
9									
10									
11		D4							
12		C4							
13									
14									
15									
16									
17									
18									
19									
20									
21									
22	D3								
GND						C1			



COMPONENT LOCATOR
SIGNAL DIRECT MODE BOARD
FIG. 8.8

SECTION IX

RATIO MODE OPTION

SECTION IX

RATIOMETER

9.1 SPECIFICATIONS

9.1.1 REFERENCE INPUT RANGE: 126V RMS maximum

9.1.2 REFERENCE INPUT IMPEDANCE: 500kΩ with Broadband Isolation
250kΩ for Non-isolated

9.1.3 RATIO RANGES:

VOLTAGE RANGE	FULL SCALE RATIO RANGE	MAXIMUM DISPLAY
10mV	20×10^{-5}	19.999
100mV	200×10^{-5}	199.99
1000mV	2000×10^{-5}	1999.9
10V	20×10^{-2}	19.999
100V	200×10^{-2}	199.99
500V	2000×10^{-2}	1999.9

Overload light flags excessive ratio, signal and reference levels.

9.1.4 ACCURACY (23°C ±5°C):

9.1.4.1 In-Phase and Quadrature Modes:

30Hz to 60Hz: (0.025% F.S. +0.05% reading)$\frac{100V}{Vref}$ + 0.16% reading

60Hz to 1.5kHz: (0.025% F.S. +0.05% reading)$\frac{100V}{Vref}$ + 0.08% reading

1.5kHz to 20kHz: (0.05% F.S. +0.08% read.)$\frac{100V}{Vref}$ + 0.25% reading

20kHz to 32kHz: (0.075% F.S. +0.1% read.)$\frac{100V}{Vref}$ + 0.3% reading

9.1.4.2 TOTAL Mode:

60Hz to 30kHz: (0.05% F.S. +0.1% read.) $\frac{100V}{Vref}$ +0.15% reading

30Hz to 60Hz
30kHz to 100kHz (0.05% F.S. +0.1% read.)$\frac{100V}{Vref}$ + 0.5% reading

9.1.5 TEMPERATURE COEFFICIENTS (0-18°C, 28-50°C)

9.1.5.1 In-Phase and Quadrature Modes

30Hz to 60Hz: (0.0015%/°C F.S. +0.003%/°C read)$\frac{100}{Vref}$ +0.015%/°C read.

60Hz to 1.5kHz: (0.0015%/°C F.S. +0.003%/°C read)$\frac{100}{Vref}$ +0.006%/°C read.

1.5kHz to 20kHz: (0.002%/°C F.S. +0.004%/°C read)$\frac{100}{Vref}$ +0.016%/°C read.

20kHz to 32kHz: (0.0025%/°C F.S. +0.005%/°C read)$\frac{100}{Vref}$ +0.02%/°C read.

9.1.5.2 TOTAL Mode

60Hz to 30kHz: .015%/°C
30Hz to 100kHz: .017%/°C

9.1.6 RESPONSE TIME: Same as standard voltage mode

9.1.7 FREQUENCY: 1 or 2 frequencies which are the same as those in the phase measurement modes. Each ratio frequency replaces one of the four phase measurement frequencies.

9.1.8 REMOTE PROGRAMMING AND DIGITAL OUTPUTS: Yes

9.2 DESCRIPTION AND OPERATING INSTRUCTIONS

The ratiometer in the Model 225 is offered at one or two frequencies, which are the same as the phase-sensitive frequencies in the instrument. Each ratio frequency replaces one of the four phase-sensitive frequencies. The ratiometer is selected by a pushbutton adjacent to the regular frequency button, or by remote control.

The measurement in this mode is the ratio of the signal voltage to the reference voltage. In the IN-PHASE and QUADrature modes, the harmonics are rejected as defined in the normal voltage mode specifications. TOTAL mode measurement is the ratio of the total signal voltage (including harmonics and noise) to the fundamental of the REFerence voltage.

The overload light flags if the reference voltage exceeds 126V or ratio exceeds 1.9999, in addition to flagging excessive signal level.

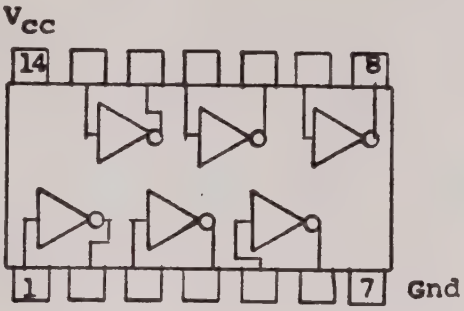
The displayed reading must be interpreted according to the range to get the actual ratio. On the millivolt ranges, the reading is multiplied by 10^{-5}; on the volt ranges, 10^{-2} to obtain the ratio. For example, if the reference was 100V and the signal 50mV, the reading on the 100mV scale would be 50.00. The actual ratio is 50×10^{-5}, obtained simply by multiplying the reading by 10^{-5}.

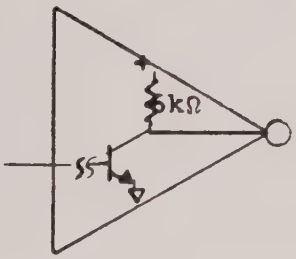
For reference voltage less than 60V, care must be taken when in the AUTORANGING mode, since the range selected by the AUTORANGING loop could result in a ratio in excess of 2.0. It is best to downrange manually until overloaded and then go to the next higher scale.

SECTION VII

SCHEMATICS

936





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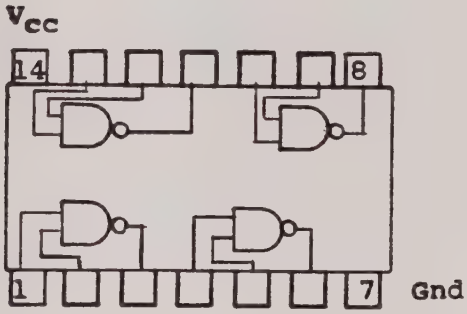

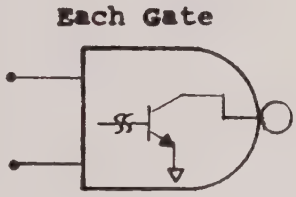

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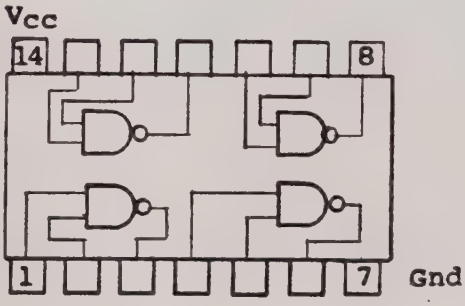

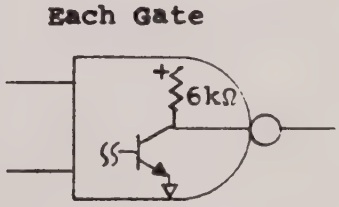

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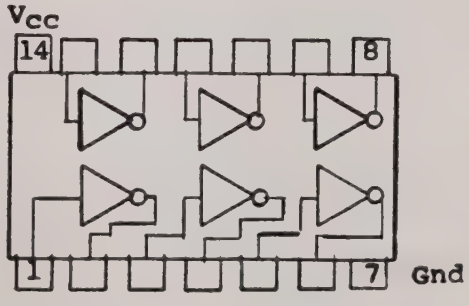
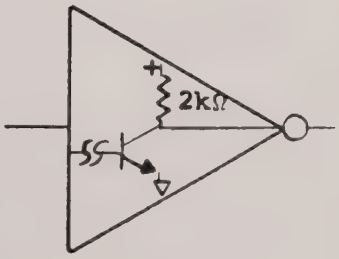
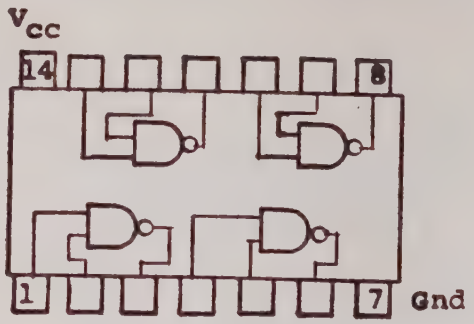
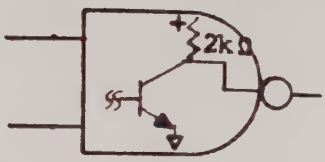




FUNCTIONAL BLOCK DIAGRAM
IC DEVICES
7.0a

949





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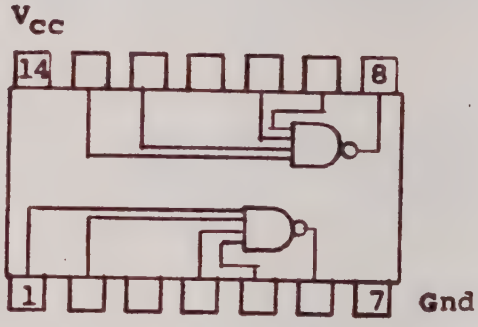
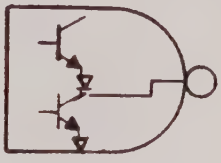
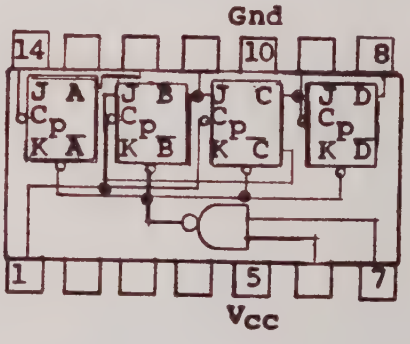
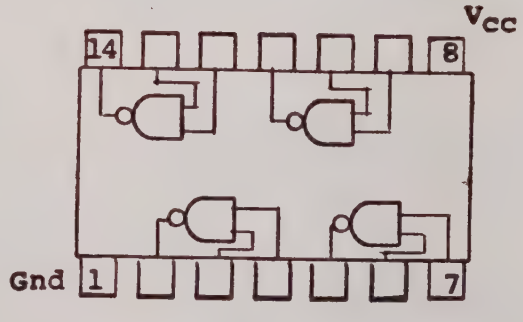


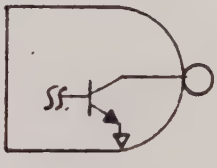


7492/9392



SP357A

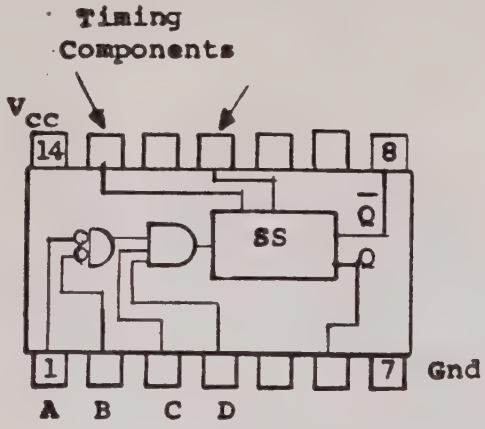




FUNCTIONAL BLOCK DIAGRAM
IC DEVICES

7.0b

9601



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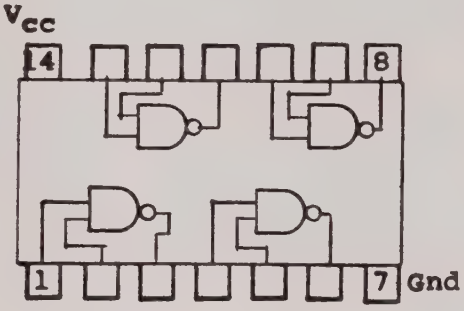

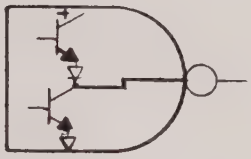

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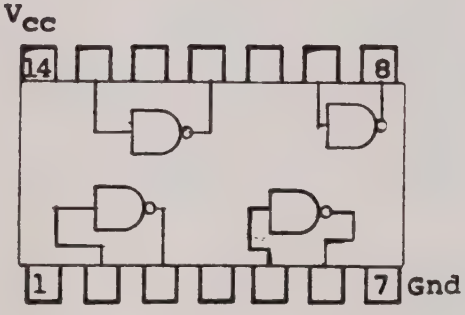

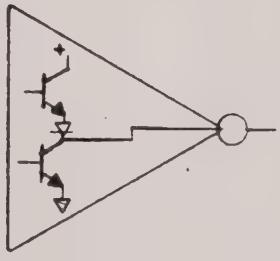

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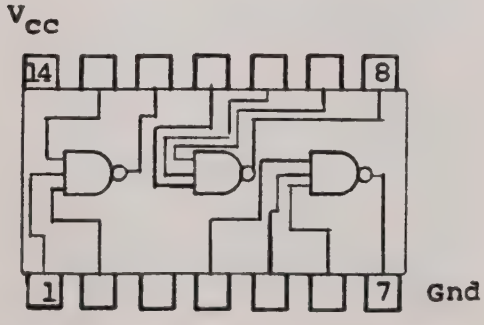
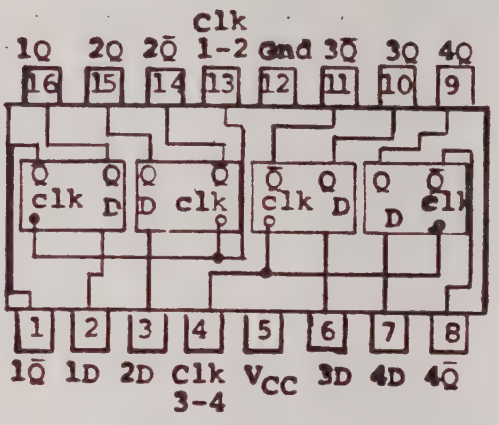


FUNCTIONAL BLOCK DIAGRAM
IC DEVICES

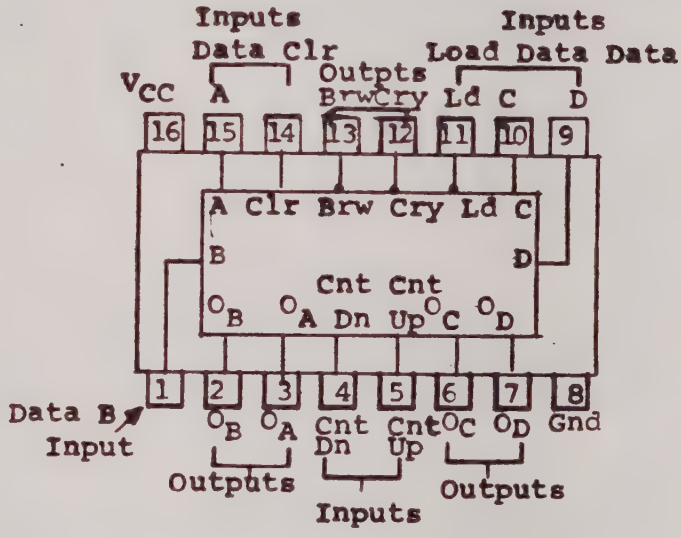
7.0c

375
or
SN7475



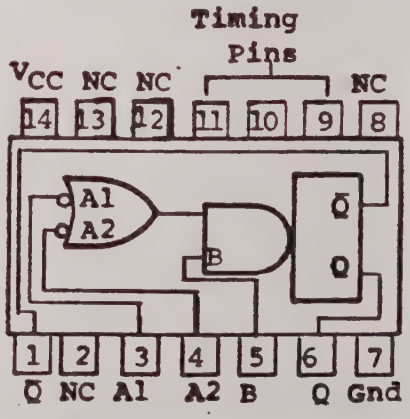
QUAD LATCH

360
or
SN74192



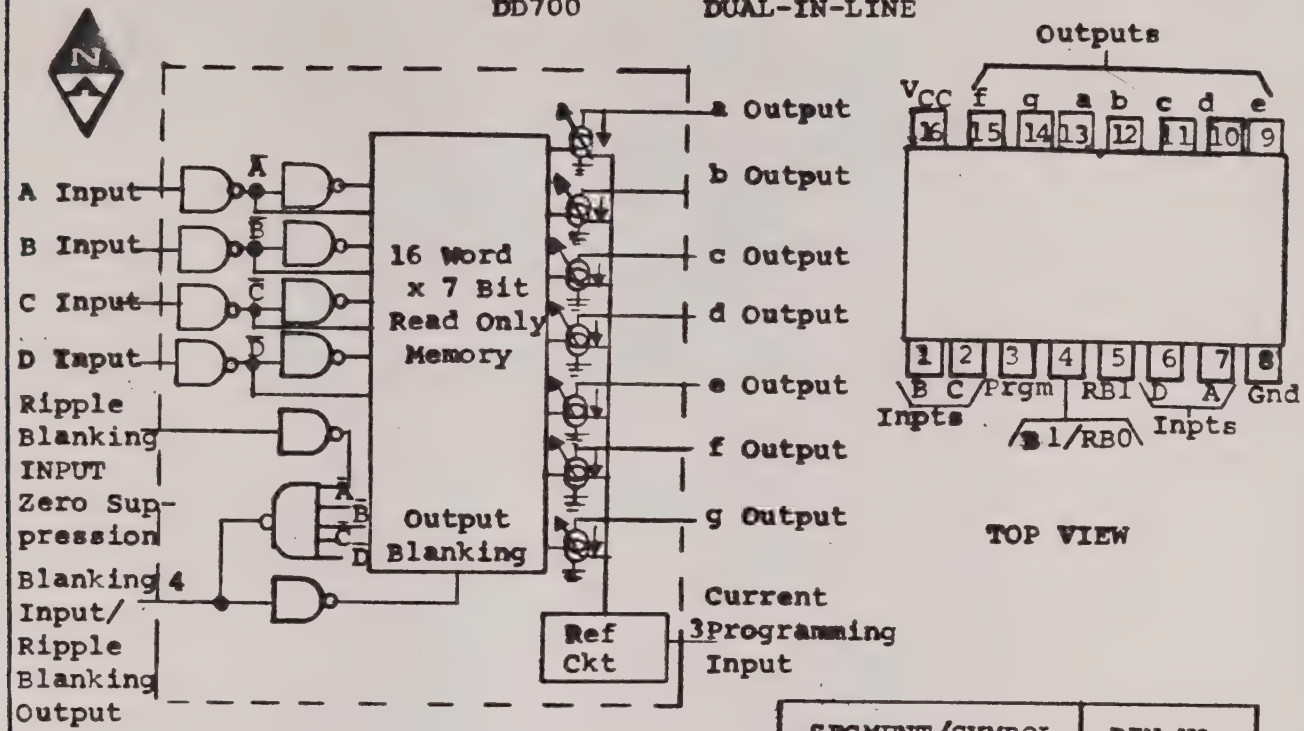
UP/DN DECADE
COUNTER

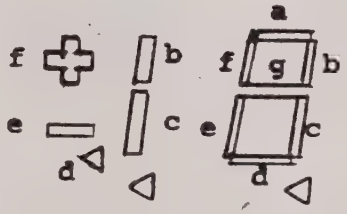
SN74121



MONOSTABLE
MULTIVIBRATOR

DD700 DUAL-IN-LINE

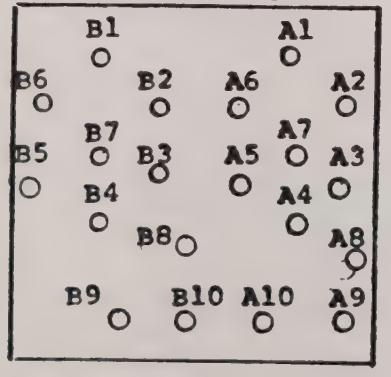




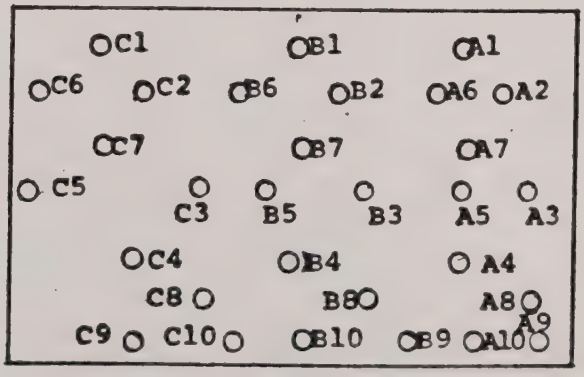
SEGMENT/SYMBOL	PIN NO.
a/*	1
b/b	2
c/c	3
d/decimal	4
e/minus	5
f/plus	6
g/*	7
decimal	8
anode	9
Keep-alive** cathode	10

*Not used in half digit
**Not used in 751 and 753

A Section - ±1
B Section - Digit



SP751
SP351



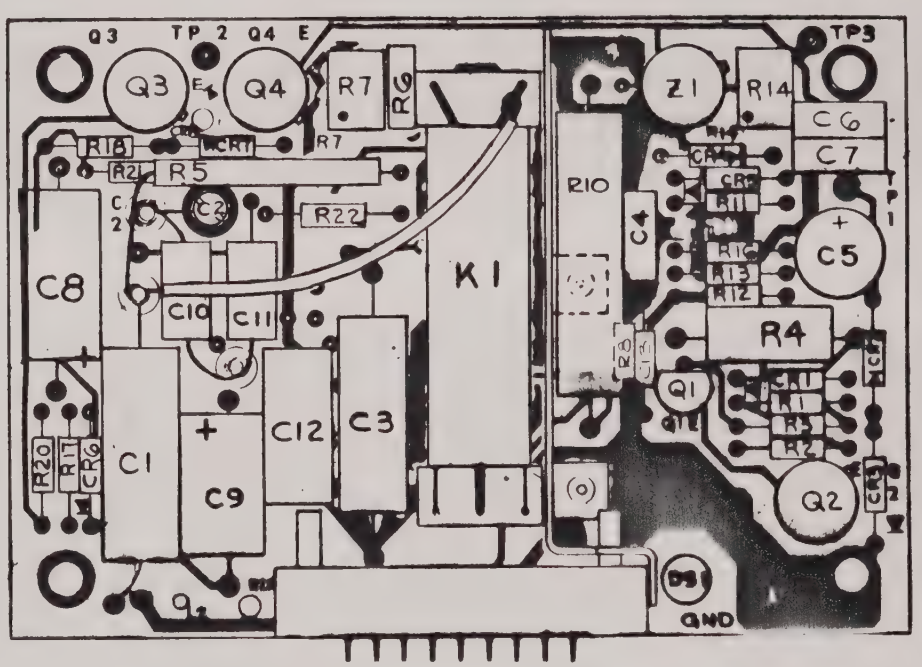
SP753
SP353

All sections are digits

7.0e

COMPONENT LOCATIONS

	R	C	CR	Q	Z	TP	L	K	DS
1	C1	C4	C1	C2	E2	D1		D3	C2
2	C1	D4	D1	C1		E4	C4		
3	C1	C3	C1	E4		E1			
4	D1	D2	D2	E4					
5	D4	D1	D2						
6	E3	E1	C5						
7	E3	E1	E4						
8	D2	D3	E4						
9		C4							
10	D2	D4							
11	D2	D4							
12	D2	C4							
13	D2	D2							
14	E1								
15									
16	D2								
17	C3								
18	E4								
19									
20	C5								
21	D4								
22	D3								
23	B4								
GND						C1			



SHOWN WITH TOP COVER REMOVED

COMPONENT LOCATOR
SIGNAL ISOLATION BOARD
FIG. 8.4

f2
Comp Loc Fig. 8.7
Schematic Fig. 7.5

*f3
Comp Loc Fig. 8.7
Schematic Fig. 7.5
or
Comp Loc Fig. 9.3
Schematic Fig. 9.2

*f4
Comp Loc Fig. 8.7
Schematic Fig. 7.5
or
Comp Loc Fig. 9.3
Schematic Fig. 9.2

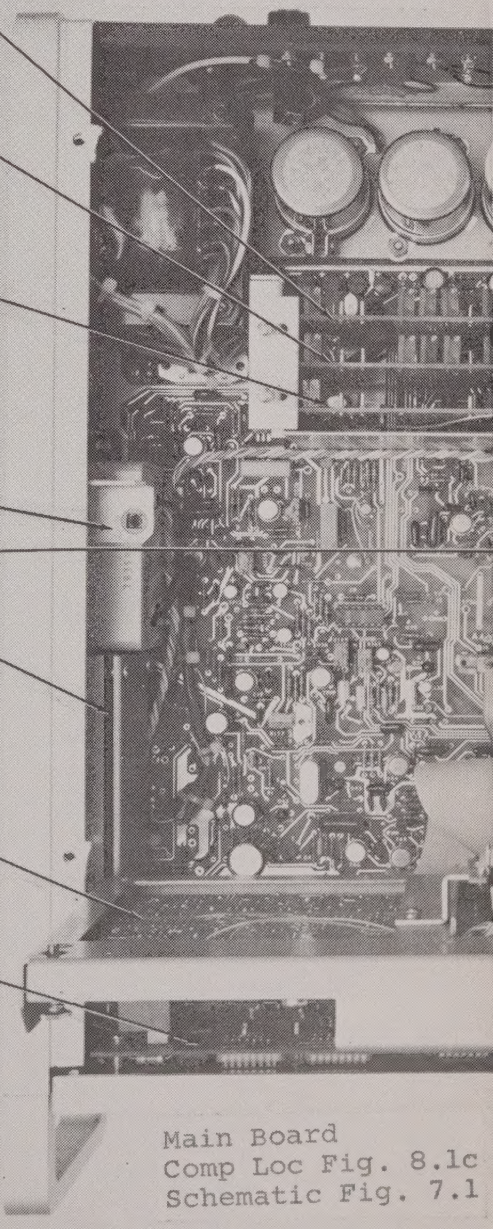
Ref Isol Xfmr Module
Schematic Fig. 7.2e

Ref Broadband
Isol Module
Comp Loc Fig. 8.5
Schematic Fig. 7.2e

A/D Board
Comp Loc Fig. 8.2
Schematic Fig. 7.3

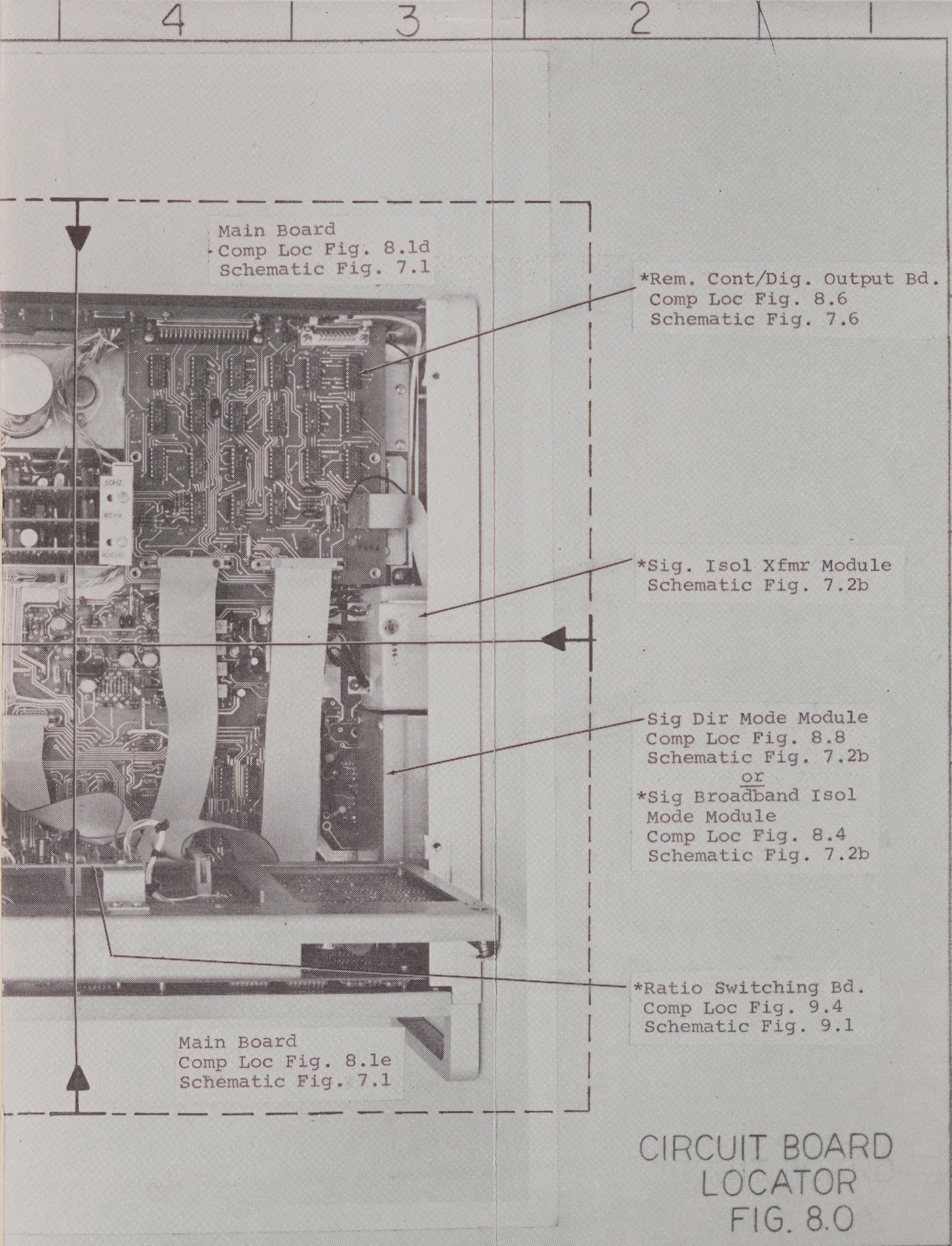
Readout Board
Comp Loc Fig. 8.3
Schematic Fig. 7.4

Main Board
Comp Loc Fig. 8.1b
Schematic Fig. 7.1



Main Board
Comp Loc Fig. 8.1c
Schematic Fig. 7.1

*OPTIONAL ASSEMBLY



CIRCUIT BOARD LOCATOR FIG. 8.0

	R	C	CR	Z	Q	K	TP	S	L	E	J
1	H6	G8		G7	G6	F8	D6	H7	D6	C2	
2	H6	F8	E8	G6	G6	E6	C8	H5	D6	C2	
3	H6	E8	E7	G3	G6	E6	D3	H3	F3	C2	
4	H8	E8	E7	G3	G6	D6	C8	C2	F3	C2	E4
5	H7	G8	D7	G2	G2	D6	C8			C2	
6	H7	G8	D7	C8	G2	D6	B8		E7	C2	H8
7	H7	E8		E3	B7	F1	C7		E7	C1	F8
8	H4	E7		E3	D8		C7		G5	B2	F1
9	H3	E8	C6	D6	E8		C6			B2	C4
10	H3	D8	D4	D4	B4		B7			C2	C4
11	E3	E7		D2	B4		D3			C1	C4
12	H2	D5	D8	D2	D8		E4			C2	E5
13	H2	D6	D8	B8	D8		E2			C1	
14	G6	D6	D8	C7	B8		F3			C2	
15	G6	D6	D8	C7	B8		E2			C2	
16	G4	D4	B8	B7	C7		E2			C2	
17	G6	C6	B8	B7	C7		D6				
18	G6	D4	C8	D2			E5				
19	G6	D4	B8	E2	G5		F2				
20	G6	D4	B8	B3	D5		F7				
21	G6	D4	D7	B3			F6				
22	G6	D4	D7	A7							
23	H2	D4		B3	B3		G2			C2	
24	H2	C8		B3			F2			C2	
25	G2	C8	C2	C1	B3		G6			B3	
26	G2	B8		A6	B3		E4			B3	
27	H2	B8	G1	A5	E2		D5			B3	
28	G2	D8	G4	B6			E6			C1	
29	G2	D8	G4	G6	B3		E6			C1	
30	H2	C8	E3	F7	B2		E2			C2	
31	G6	D8	E3	F7	B3		B8			G2	
32	F8	C8	E2	F7	B3		C7			G8	
33	E8	C8	E2	G7	F4					G8	
34	E8	C8	E2	F7	B3		G5				
35	E8	C9	E2	D5	A6		G3			F8	
36	E8	C8	E3	E5	D5					F8	
37	D7	C8		G8	E5					F8	
38	D8	C8	E3	F6	D5					F8	
39	D8	C8	D8	F7	E6					F8	
40	E8	C7	D8	F6	E6					F8	
41	D7	C7	G6	E6	F2					F8	
42	D8	B8	G6	E6	F2					F2	
43	E7	B7	G6	F7	C1						
44	E8	B7	E8	F3						F2	
45	E8	B7	E8	G1	F3					F1	
46	E7	C7	C2	G3	F2					F1	
47	D7	C7		F4	G3					F1	
48	D7	C7		G3						F1	
49	E8	C7	D5		G1						
50	E7	C7	D5	G3						F1	
51	D6	C7	E5	G6	G3					F1	
52	D6	B7	E6	G5	G4						
53	D6	C7	F6	G6	D3						
54	D6	C7	F6	F5	E8					G4	
55	E8	B7	G4	F5	E8						
56	E6	C2	E5	G5	B6						
57	D4	D2	C1	G5							
58	D4	D2	F3	G5						G7	
59	D4	D2	E6							G7	
60	D4	D2	G3	F5						G7	

	R	C	CR	Z	E
61			F4	E7	G7
62			F4	C2	
63		D3	G1		F8
64	D4	D2	G1		C1
65	C8	D2	G1		C1
66	B9	D2	G3		G9
67	C8	D2	G2		G2
68	C8	E2			C6
69	C8	D2	G6		C6
70	D8	E2	G4		C6
71	D8	E2	D3		G8
72	C8	E2	F6		G5
73	C8	F2	D3		H2
74	C8	E2	F2		G7
75	C8	E2	D3		G7
76	D8	E3	C5		G2
77	C8	E3			G5
78	B8	F3			D8
79	B8				D8
80	C8				F8
81	B8	E2			F2
82	C8	E2			F1
83	C8	E3			D8
84	C8	E3			G4
85	C8	D5			E8
86	B8	E2			E8
87	C8	C2			
88	C8	B3			+15V
89	C8	B5			B5
90	C7	B5			
91	C7	B3			-15V
92	C7	B5			
93	C7	B5			B5
94	C7	B4			
95	C7	B6			
96	C7	C6			+5V
97	C7	C6			
98	C7	B7			C6
99	B7	D5			
100	C7				
101	B7	D4			
102	B7				
103	B7				
104	B7	E5			
105	C7	E5			
106	C6				
107	C7	F6			
108	B7	F2			
109	C6	F2			
110	C2	G2			
111	C1	F2			
112	D2	F2			
113	C2	F2			
114		F2			
115	D2				
116	C2	F2			
117		F2			
118		F2			
119	D3	G2			
120	D2	F3			

	R	C
121	D3	F4
122	H7	F3
123	H7	F3
124	H6	F3
125	G5	F4
126	G5	G3
127	D2	G3
128	D2	G4
129	D2	F4
130	D2	F4
131	G5	F4
132	G5	F4
133	E2	G2
134	H4	F3
135	D2	G5
136	E3	G4
137	E3	F6
138	E3	D3
139	E2	D2
140	E2	
141	F2	
142	E2	C2
143	E3	D2
144	E2	D2
145	E2	C2
146	E3	F2
147	E2	F2
148	E3	F3
149	E3	G5
150	E3	D5
151	E2	D5
152	E2	
153	E3	
154	E3	
155	E2	
156	E2	G7
157	F2	G7
158	F3	G7
159	E3	G7
160	E3	E8
161	E3	E7
162	F3	E7
163	E3	E7
164	F4	D7
165		D7
166	F3	D7
167	G6	D7
168	G6	E4
169	D4	F6
170	C8	C8
171	D8	D7
172	E3	F8
173	E3	E4
174	E4	E4
175	E4	D3
176	E4	D3
177	E4	E3
178	E6	E7
179	E6	F5
180	E6	D2

	R	C
181	A8	C2
182	C6	C2
183	C6	D1
184	D4	
185	D4	
186	D5	
187	D5	
188	E5	
189	D5	
190	E5	
191	E5	
192	E5	
193	E5	
194	E6	
195	E6	
196	D4	
197	D4	
198	F6	
199	F6	
200	F6	
201	D6	
202	E5	
203	E5	
204	D5	
205	E6	
206	E6	
207	E6	
208	E6	
209	E6	
210	E6	
211	F6	
212	F2	
213	F2	
214	F2	
215	F2	
216		
217	F2	
218	F2	
219	F2	
220	G2	
221	F3	
222	F3	
223	F3	
224	F2	
225	F3	
226	F4	
227	G3	
228	G3	
229	F3	
230	F3	
231	F3	
232	G4	
233	F4	
234	F4	
235	F4	
236	F4	
237	G1	
238	G1	
239	G2	
240	G2	

	R
241	G4
242	
243	
244	G3
245	G3
246	G3
247	G3
248	F5
249	F5
250	G4
251	G4
252	
253	
254	G4
255	G3
256	G8
257	F3
258	D2
259	D2
260	H7
261	D3
262	E9
263	D3
264	D3
265	D3
266	D8
267	D2
268	E2
269	D5
270	D5
271	F8
272	G3
273	G3
274	F4
275	F4
276	F3
277	G4
278	D5
279	D5
280	
281	E8
282	D1
283	D1
284	D1
285	D1
286	C2
287	C2
288	F6
289	D2
290	D2
291	D2
292	E9
293	F6
294	F6
295	D6
296	B4
297	B4
298	F8
299	F6
300	G2

	R
301	B4
302	D6
303	F1
304	F2
305	E5
306	E8
307	E8
308	D6
309	E5
310	D2

COMPONENT LOCATOR

MAIN BOARD FIG. 8.1a

TO LOCATE A COMPONENT ON THE COMPONENT LOCATOR, LOCATE ZONE USING ABOVE TABLE (ZONE FOR R1 IS H6, ZONE FOR C6 IS G8). COMPONENT CAN THEN BE LOCATED ON COMPONENT LOCATOR WITHIN THE ZONE INDICATED.

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